THE

JOURNAL OF GEOLOGY

JULY–AUGUST, 1913

THE SIGNIFICANCE OF RECENT DEVELOPMENTS IN THE PRE-CAMBRIAN STRATIGRAPHY OF THE LAKE SUPERIOR–LAKE HURON REGION

MORLEY E. WILSON
Geological Survey, Ottawa

INTRODUCTION

The geological investigations carried on during the last decade in the northern parts of the Canadian provinces of Ontario and Quebec have added much to our knowledge of the pre-Cambrian terranes of that region, notably so in the Lake Timiskaming district, where the discovery of the silver-bearing veins at Cobalt and of the auriferous quartz lodes at Porcupine has led to extended exploration in the adjoining country. And it is now generally accepted that the pre-Cambrian rocks of northwestern Quebec and northeastern Ontario fall naturally into two strikingly different divisions, separated by a most profound (pre-Huronian) erosion interval. It is also possible, as will be shown in the following pages, that the ancient peneplain or paleoplain formed during this interval, was continuous with the pre-Animikie or Eparchaean[1] erosion plane which occurs in the region north and west of Lake Superior, and that the so-called Lower or Lower-Middle Huronian sediments found in the same locality are in reality a part of the basement complex and pre-Huronian in age.

[1] A. C. Lawson, *Bull. Univ. of Cal.*, III, 50–62.

PRINCIPLES OF PRE-CAMBRIAN CORRELATION

Since pre-Cambrian rocks are generally unfossiliferous, their correlation must be based on either their lithological similarity, their similar stratigraphical relations or their similarity of structure. The criteria of pre-Cambrian correlation may thus be enumerated as follows: (1) stratigraphical relations; (2) lithological character; (3) degree of folding and metamorphism; (4) relationship to igneous intrusions. These will accordingly be used as the basis of the correlations suggested in the following pages.

LAKE HURON–LAKE TIMISKAMING–LAKE MISTASSINI REGION

The earliest stratigraphical investigation of the pre-Cambrian rocks occurring in the Lake Superior–Lake Huron region was that of Logan and Murray on the north shore of Lake Huron, where they found a great series of slightly folded sediments resting unconformably on a basement complex consisting chiefly of granite and gneiss. To the rocks of the first group the name Huronian was given, while the granite and gneiss were correlated with the similar Laurentian granite and gneiss occurring in the vicinity of the Ottawa farther to the eastward. From this classification it is apparent that, theoretically at least, Logan recognized the divisibility of the pre-Cambrian into a Huronian system and an older complex, although both he and his successors in the later reconnaissance work carried on in other districts included greenstones, green schists, and other rocks in the Huronian which are now known to belong to the basement complex.

It was not until about ten years ago, when detailed geological work was begun in the Timiskaming region, that it was found that in this district as on the north shore of Lake Huron a series of slightly disturbed sediments rested in striking erosional and structural unconformity on a basement complex.[1] This complex contained a large proportion of volcanic rocks which were then called Keewatin on the assumption that they were the equivalent of similar rocks occurring in the Lake of the Woods region 500 miles to the westward.[2] In this way it became customary to divide the older complex of the Timiskaming region into two divisions, (1) the

[1] A. E. Barlow, *Ann. Rep. G.S.C.*, XV, 127*a*, 1903.

[2] W. G. Miller, *Ann. Rep., Ont. Bur. of Mines*, Pt. II, 1905.

Keewatin, which included the surface rocks, composed largely of volcanic flows, and (2) the Laurentian, consisting largely of plutonic granite and gneiss. During the last few years, however, has it been found that the so-called Keewatin complex includes a much larger proportion of sedimentary rocks—conglomerate, arkose, greywacke, slate, etc.—than was formerly supposed, and to these various local names—Pontiac schist,[1] Fabre Series,[2] Timiskaming Series,[3] Sudbury Series, etc.—have been given. These rocks have been found in almost every area where detailed geological work has been carried on. They occur in the Sudbury district, in the vicinity of Lake Timagami, in the Larder Lake district, in the Cobalt region, in the Porcupine district and in numerous localities in northwestern Quebec. In the last-mentioned region a belt of fine-grained, rusty mica schist, which contains squeezed pebbles of granite and greenstone, has been traced continuously for 100 miles by J. A. Bancroft and the writer. Throughout all this distance the schist is intruded by dikes of granite, aplite, and pegmatite, showing conclusively that it is older than at least part of the Laurentian gneissic complex. In defining the various series to which these rocks have been referred, it has been assumed in most cases, (1) that they belong to the Huronian, and (2) that they are younger than all the volcanics of the basement complex.

Both of these assumptions are probably unwarranted. In objection to the use of the name Huronian for the sediments occurring in the volcanic complex, it might be pointed out that they occur throughout an area of many thousand square miles, and everywhere possess characteristics which are distinctly at variance with those of the typical Huronian. They form a part of a basement complex which, as shall be shown later, probably lies stratigraphically below the original Huronian. Lithologically they have little in common with the original Huronian, and unlike the Huronian, they are everywhere highly folded, foliated, and intruded by granite batholiths. The second of these assumptions implies that the sedimentary rocks are stratigraphically as well as lithologically separate from the volcanics, a conclusion which is con-

[1] M. E. Wilson, *Sum. Rep. Geo. Surv. Dept. of Mines, Can.*, p. 175, 1909.

[2] R. Harvie, *Geology of a Portion of Fabre Township* (Dept. of Mines, Que.), 1911.

[3] W. G. Miller, *Eng. and Min. Jour.*, XCII, p. 648, 1911.

trary to the facts, for, while the presence of a heterogeneous assortment of pebbles in the conglomerate indicates that a great erosion interval is probably represented, there is evidence, in some localities, that the sediments and volcanic flows are interbedded and consequently, if two series are present, it is evident that volcanic flows occur in both. In many localities either because of the highly deformed condition of the rocks, or because of the paucity of exposures, or because of the lithological similarity of the volcanic flows, it is not possible to separate these various rocks into stratigraphical divisions. For these reasons it seems necessary at present to class them together into one group regardless of possible differences in age, making merely such subdivisions as are convenient for the purpose of lithological description. In accordance with the foregoing conclusion the writer has adopted the term Abitibi group to include all the surface rocks, i.e., the sediments and volcanic flows, of the older complex occurring in the Timiskaming region. Since the surface rocks are placed in the Abitibi group, the plutonic granite and gneiss must naturally be referred to the Laurentian. But it is important to note that the Laurentian according to this definition, most probably includes granitic rocks of at least two periods of intrusion, as shown by the presence of granite pebbles in conglomerate which is itself intruded by granite.

The flat-lying sediments which rest on the base-leveled surface of the basement complex in the Timiskaming region, when first recognized as distinct from the underlying volcanics, were called Lower and Middle Huronian,[1] but as there was some doubt as to which particular division of the Huronian they should really be referred, they are now generally known as the Cobalt series.[2] They outcrop throughout a region extending from the Abitibi district in Quebec to the Sudbury district in Ontario, and occupy an area of not less than twenty thousand square miles. Throughout all this area they rest on a remarkably uniform erosion surface, which might be described as a fossil peneplain.

In the Chibougamau district near Lake Mistassini, 200 miles to the northeast of the Timiskaming region, there is a series of slightly disturbed sediments which resembles the Cobalt series

[1] *Ann. Rep., Ont. Bur. of Mines*, Pt. II, 1905.

[2] W. G. Miller, *Eng. and Min. Jour.*, XCIII, 643, 1911.

both in its lithological character and in the stratigraphical succession of its members, and like the Cobalt series rests on the trunkated surface of a basement complex.[1] Throughout the intervening distance between Lake Timiskaming and Lake Chibougamau, no outcrops of the Cobalt series have been described, but the Abitibi group and the Laurentian are typically developed throughout the whole interval. From these facts it may be concluded that the pre-Cobalt series erosion plane, the Abitibi group and the Laurentian extend eastward to the Chibougamau district.

From the evidence already cited it might be inferred that the pre-Cobalt series erosion plane is also the equivalent of that which underlies the original Huronian rocks on the north shore of Lake Huron, but since a large part of the conclusions of this paper are based on the correlation of these two planes, it is important that the evidence be stated in full. In support of their correlation it might first be pointed out that the Cobalt series and the two original Huronian series are structurally and lithologically very similar, even to the presence of a sea-green quartzite containing pebbles of jasper and quartz. It is true that until recently, it was thought that the limestone was absent in the Cobalt series, but as that series is traced southward it changes somewhat in character, and limestone beds have been found to be present in the district northeast of Sudbury.[2] Not only are the original Huronian rocks similar to the Cobalt series, but there is no other series in the Timiskaming region which resembles them either in lithological character, structure, or relationship to batholithic intrusions. The basement complex which underlies the original Huronian rocks has not been studied in detail, but like that beneath the Cobalt series, it consists in the main of metamorphosed volcanic flows intruded by granite and gneiss. Thus in both districts an older complex occurs which is separated from the overlying slightly disturbed sediments by erosion planes, which would coalesce if projected across the interval which intervenes between the known occurrences of the Cobalt series and the original Huronian.

From the foregoing discussion it follows that throughout the

[1] *Rep. on the Geol. of the Chibougamau Region* (Dept. of Mines, Que.), pp. 134–38, 1911.

[2] W. H. Collins, *Sum. Rep. Geo. Surv. Dept. of Mines, Can.*, 1913.

Lake Huron–Lake Timiskaming–Lake Mistassini region, pre-Cambrian sedimentary rocks occur here and there, which were laid down upon the surface of a basement complex. This of course does not make it necessary that the original Huronian rocks, the Cobalt series and the rocks described as Huronian in the Chibougamau district, are wholly contemporaneous. In fact this is scarcely probable since there are two series present[1] in the original Huronian group of rocks and, as far as known, only one elsewhere. Nevertheless it is evident that all of these younger sediments were derived from similar sources, that they originated under somewhat similar conditions, that their history since their deposition has been similar, and that the floor upon which they were deposited was the same.

THE LAKE SUPERIOR REGION

Having shown that an early pre-Cambrian paleoplain extends throughout such a wide area of country in northwestern Quebec and northeastern Ontario, two questions now present themselves: (1) does this pre-Huronian erosion plane extend throughout the Lake Superior region, and (2) what rocks in that area correspond to the basement complex of the Lake Huron–Lake Timiskaming–Lake Mistassini region?

From the geological reports which have been published with regard to various districts in northern Ontario and the adjacent portions of United States to the west of Lake Superior, it is known that throughout the wide area of country which extends from the Timiskaming region to the Vermilion district in Minnesota, there is a basal (pre-Animikie) complex composed in part of volcanic rocks and in part of granite and gneiss, and in almost every locality where detailed work has been carried on—on the east shore of Lake Superior near Batchawana bay,[2] in the Michipacoten district,[3] near Heron bay on the northeast shore of Lake Superior,[4] in the Nipigon district,[5] in the vicinity of Port Arthur,[6] in the region

[1] According to C. R. Van Hise, *Bull. Geo. Soc. Am.*, p. 5, 1908.

[2] *Ann. Rep. Ont. Bur. of Mines*, p. 127, 1892.

[3] *Ibid.*, pp. 152–85, 1902.

[4] *Ibid.*, p. 127, 1892.

[5] *Ibid.*, 1908, 1909; *National Transcontinental Railway between Lake Nipigon and Sturgeon Lake* (Geol. Surv. Dept. of Mines, Can.), 1908; *Geology of the Nipigon Basin*, Memoir No. 1 (Geol. Surv. Dept. of Mines, Can.), 1910.

[6] *Ann. Rep. Ont. Bur. of Mines*, pp. 254–60, 1905.

between Lake Savant and Lost Lake,[1] in the Lake of the Woods and Rainy Lake districts,[2] in the Vermilion district,[3] and at Steep Rock Lake,[4] it has been found that highly metamorphosed conglomerates, slates and schists of sedimentary origin occur in association with the volcanics and, as in the pre-Cobalt series complex of the Timiskaming region, the conglomerate although intruded by granite contains granite pebbles. But in only two localities—the Vermilion district and Steep Rock Lake—has the conglomerate been found resting unconformably on the surface of the older granite from which its pebbles were derived.

Here and there this basement complex is overlain by two series of almost flat-lying sediments, the older of which is known as Animikie and the younger as Keweenawan. In some places, as on the shore of Thunder Bay, both series are present; but in others the Animikie occurs alone, or the Animikie is absent and the Keweenawan rests directly on the surface of the complex.

The names which have been applied to the various formations composing the (pre-Animikie) complex found in the region north and west of Lake Superior, have varied in different localities and at different times. For many years following the work of Logan and Murray on the north shore of Lake Huron, the geologists who investigated these pre-Cambrian terranes, with but one notable exception, called the granite and gneiss Laurentian and the volcanic complex Huronian. But A. C. Lawson who reported on the geology of the Lake of the Woods and Rainy Lake regions for the Canadian Geological Survey, departed from the general custom and adopted a local nomenclature. According to Lawson's classification the granite and gneiss were Laurentian, but the volcanics and sediments were grouped into an Ontarian system which had two divisions, the Coutchiching series, largely composed of sedimentary mica schist and the Keewatin, consisting for the most part of volcanics. In the Vermilion district of Minnesota, where much detailed geological work has been carried on since Lawson's reports

[1] *National Transcontinental Railway between Lake Nipigon and Clay Lake* (Geol. Surv. Dept. of Mines, Can.), 1909; *Ann. Rep. Ont. Bur. of Mines*, 1910.

[2] *Ann. Rep. G.S.C.*, I, Part CC, 1885; *ibid.*, III, Part F, 1887-88.

[3] *U.S.G.S. Mon.*, XLV, 1903; *ibid.*, Vol. LII, 1911.

[4] *Memoir No. 28* (G.S. Dept. of Mines, Can.), 1912.

were published, the volcanic rocks of the complex have been classed as Keewatin in accordance with Lawson's nomenclature, but the name Laurentian has been limited to the older granite which lies unconformably beneath the Ogiskie conglomerate and Knife Lake slates, while these sediments, along with the younger granite which intrudes them, have been designated Lower or Lower-Middle Huronian. The scheme of classification worked out in the Vermilion region is essentially the same as that indorsed by the International Committee in their report on the pre-Cambrian nomenclature of the Lake Superior region[1] and has been generally adopted, as far as practicable, by Canadian geologists engaged in geological work in the pre-Cambrian regions of northern Ontario and Quebec.

But in applying this classification in the Lake Huron–Lake Timiskaming region, serious difficulties have been encountered, for the rocks known as Lower-Middle Huronian in the region north of Lake Superior are similar in every respect to the younger (Timiskaming, etc.) series occurring in the pre-Cobalt series complex, whereas the name Lower-Middle Huronian implies that they are approximately equivalent in age to the Cobalt series and the original Huronian, which they resemble in no particular whatever. While it might be objected that the Lower-Middle Huronian rocks of the region north of Lake Superior are too far distant from the rocks composing the Timiskaming series for their correlation, yet, if the rocks occurring in these two regions are to be correlated at all, then the Lower-Middle Huronian must certainly be correlated with the pre-Huronian Timiskaming series, rather than with the Cobalt series or the original Huronian. At any rate, it is at least probable, from the remarkable lithological and structural similarity of the basal pre-Cambrian rocks occurring throughout the whole region from Lake Superior to Lake Timiskaming, and the evidence of the presence of an erosion interval in the pre-Cobalt series complex, similar to that beneath the Ogiskie conglomerate in the Vermilion region, that the rocks which underlie the Cobalt series in the Timiskaming region are the same as those beneath the Animikie series in the region north and west of Lake Superior and that the pre-Huronian paleoplain occurring in the Lake Huron–Lake

[1] *Jour. of Geol.*, XIII, 89–104, 1905.

Timiskaming region was originally continuous with the pre-Animikie or Eparchaean erosion plane. It also follows from this conclusion that the name Lower or Lower-Middle Huronian for any series of rocks in the basement complex occurring to the north and west of Lake Superior is inapplicable; nor does the limitation of the name Laurentian to the older granite in the Vermilion region seem advisable, for this usage is not only contrary to the original definition of the term, but also contrary to the requirements of our nomenclature, since in many localities it is impossible to state whether a particular granite or gneiss belongs to the younger or older of the granitic rocks recognized to be present in the pre-Cambrian basal complex.

The conclusion that the rocks classed as Lower or Lower-Middle Huronian in the region north of Lake Superior are probably pre-Huronian in age was reached from two premises: (1) that the same series of rocks is present in the complex which underlies the Cobalt series, and (2) that the pre-Cobalt series complex also underlies the original Huronian rocks on the north shore of Lake Huron. By making a direct comparison of the Lower-Middle Huronian rocks occurring to the north of Lake Superior with those occurring to the south of the lake, this correlation may be tested in another way. In the region south of Lake Superior, as in the other pre-Cambrian areas, there is a basement complex composed of greenstone and green schist intruded by batholiths of granite and gneiss, but in that locality the complex is overlain by a succession of four rock series. These, named in ascending order, are known as Lower Huronian, Middle Huronian, Upper Huronian, and Keweenawan respectively. The Lower and Middle Huronian are believed to be the equivalent of the original Huronian on the north shore of Lake Huron, while the Upper Huronian is correlated with the Animikie series of the north shore of Lake Superior. The Keweenawan series, as the name implies, is also believed to correspond to the series of the same name on the north shore of Lake Superior. These correlations have been generally accepted[1] and are almost wholly in accord with the criteria of pre-Cambrian correlation, so that for the purpose of this discussion they may be taken as repre-

[1] R. D. Irving, *Am. Jour. Sci.*, XXXIV, 204, 1887.

senting the facts. And since there is a series of rocks in the older complex north of Lake Superior classed as Lower-Middle Huronian, it has evidently been assumed that it is the equivalent of the Lower and Middle Huronian occurring to the south of Lake Superior. Accordingly, by comparing the Huronians of the two regions, we can ascertain on what facts their correlation has been based.

1. The Huronian rocks of the southern area are largely quartzites, limestones, dolomites, and slates, while those of the northern area consist for the most part of conglomerate slate and mica schist. Their correlation has therefore not been based on the similarity of their lithological character.

2. The Huronian of the north is intruded by batholiths of granite and gneiss; that of the south is not so intruded. It is also evident therefore that their correlation cannot be attributed to any similarity in their relationships to igneous intrusions.

3. The northern Huronian has not only been more highly folded and deformed than the southern, but the deformation occurred at a much earlier period in the north than in the south, for the Animikie rocks of the north are not only almost flat-lying, but they rest on a peneplained surface, so that the deformation in the underlying complex was complete long before the Animikie sediments were laid down. To the south of Lake Superior, on the other hand, the Animikie and Keweenawan rocks are highly folded, and hence, if the Animikie and Keweenawan deformation were eliminated throughout the whole Lake Superior region, the southern Huronian would be but slightly disturbed, whereas that of the north would be just as much folded and deformed as at present. It is again apparent therefore, that the northern Lower-Middle Huronian has not been correlated with that of the south, on the grounds that both have been folded and deformed to the same degree or at the same time.

4. The Huronian to the south of Lake Superior like that to the north, rests unconformably on the surface of a complex composed of greenstone, greenschist and iron formation (Keewatin) intruded by granite and gneiss, so that the stratigraphical relations of the Huronians in both localities are apparently the same; and it was evidently upon this fact that their correlation was based, but in

considering the stratigraphical relations of greater importance than all the other criteria combined, the geologists who made the correlation ignored the possibility of overlap.

The geological investigations carried on throughout the region north of Lake Superior have shown that the rocks classed as Lower-Middle Huronian occur here and there throughout the basal complex as trunkated synclinal remnants, and that relatively their areal extent is exceedingly small; and since the total area of the rocks which have been differentiated as Keewatin in the region south of Lake Superior is only 60 square miles in extent,[1] it is possible that the stratigraphical relations observed are due to the fact that one of these synclinal remnants does not happen to occur in this limited area. If this were the case, then the pre-Huronian complex to the south of Lake Superior and the pre-Animikie complex to the north of the lake would be equivalent, although the stratigraphical relations of the Huronian to the south and Huronian to the north would be apparently the same. Consequently, although the stratigraphical relations of the so-called Lower-Middle Huronian of the Vermilion district are apparently similar to those of the Lower and Middle Huronian to the south of Lake Superior, yet from the consideration of the other facts—that the two groups of rocks are lithologically unlike, that those of the north are intruded by batholiths of granite and gneiss while those of the south are not so intruded, and that the deformation and folding in the south occurred long after that in the north—it must be concluded that the evidence in favor of their correlation is not sufficiently conclusive to preclude the possibility of an alternative hypothesis.

CONCLUSION

The evidence and the conclusions inferred from the evidence as stated in the preceding pages, may be summarized briefly as follows: (1) The paleoplains which underlie the original Huronian rocks on the north shore of Lake Huron and the Cobalt series in the Timiskaming region were originally continuous. (2) The complex which underlies the Cobalt series in the Timiskaming region and that which underlies the Animikie series in the region

[1] *U.S.G.S. Mon.*, Vol. LII, Plate I, 1912.

north of Lake Superior are the same. (3) From (1) and (2) it is inferred that the pre-Huronian erosion plane was also originally continuous with the pre-Animikie or Eparchaean erosion plane, and that the rocks classed as Lower-Middle Huronian in the region north of Lake Superior are therefore a part of the basement complex and in reality pre-Huronian in age. (4) If the rocks classed as Lower and Middle Huronian in the region south of Lake Superior have been correctly correlated with the original Huronian, then these series must also be younger than the Lower-Middle Huronian of the region north of Lake Superior; (5) A direct comparison of the Lower-Middle Huronian of the region north of Lake Superior with the Lower and Middle Huronian occurring to the south of Lake Superior shows that the correlation of these series is based on evidence from which an alternative inference conforming to the conclusion cited in (3) may be drawn.

With the progress of geological investigation in the pre-Cambrian terranes of the Canadian oldland, new facts are constantly being added to our knowledge of their stratigraphy, and from the evidence now available it can be reasonably inferred that the pre-Cambrian rocks throughout the whole of the Lake Superior region and eastward through northern Ontario and western Quebec, fall naturally into two great divisions, an older complex and a group of younger rocks, which differ from the complex in that they generally contain a much larger proportion of sediments, are generally much less highly folded and metamorphosed, and as far as geological investigation has shown, are nowhere intruded by batholiths of granite or gneiss. This younger group of rocks includes (1) the Cobalt series in the Timiskaming region, (2) the Animikie and Keweenawan series in the region north of Lake Superior, (3) the original Huronian series on the north shore of Lake Huron, and (4) the rocks known as Lower Huronian, Middle Huronian, Upper Huronian and Keweenawan in the region south of Lake Superior. This conception of the stratigraphical relationships of these various younger pre-Cambrian series involves no unusual phenomena, for just as in later geological periods Cretaceous, Silurian, and other sediments of different ages were deposited on the surface of the same basal complex, so in Huronian

time, the Animikie series might be laid down on the same erosion surface on the north shore of Lake Superior, as the Huronian on the south. If the Lower and Middle Huronian series are not present in the region north of Lake Superior, it must simply be inferred that they were never deposited in that region, or, if deposited, they were eroded away before the Animikie sediments were laid down, and that the geological time represented by the Eparchaean interval in the region north of Lake Superior is represented in the region south of the lake, by three erosion intervals and two series of sediments.

The rocks comprising the basement complex which everywhere underlies the younger pre-Cambrian series, have suffered so many vicissitudes that although there is evidence, in many localities, that two series of surface rocks and granitic batholiths of two periods of intrusion are present, yet it is not possible in many places to separate the rocks stratigraphically from one another. For this reason the only *regional* classification practicable *at present*, is to divide the complex into two divisions according as to whether they belong to the plutonic or surface types. For the plutonic rocks the name Laurentian has been generally used, and while this name, according to the original conception of Logan, might be more properly referred to the whole basement complex, it has since been referred to the plutonic types so constantly, both by Logan and by his successors, that it seems best to use it with that significance. For the surface rocks of the complex, the writer has used the name Abitibi group in the Timiskaming region, but this probably corresponds to the Ontario system into which Lawson grouped the Keewatin and Coutchiching series occurring in the Lake of the Woods and Rainy Lake regions. The subdivisions of the basement complex (Archaean) according to this classification would thus be as follows:

HURONIAN

PRE-HURONIAN PALEOPLAIN

Basement Complex	Laurentian	Younger Laurentian granite and gneiss.
		Older Laurentian granite and gneiss.
	Ontarian or Abitibi group	Composed of at least two series, to be given local names where subdivision is possible.

The regional correlation of pre-Cambrian rocks from the nature of the evidence upon which it is based must always be to a degree hypothetical, but so long as it is logically inferred from a reasonable number of facts and its hypothetical character is kept in mind by geologists, it serves a useful purpose in the progress of our science. In the report of the Special Committee on the Lake Superior region, certain sedimentary rocks included in the basement complex to the north of Lake Superior were called Huronian, and thus tacitly correlated with the Huronian rocks occurring in the region south of Lake Superior and on the north shore of Lake Huron. The purpose of the present paper has been to point out that from a careful consideration of the facts now at hand, it must be concluded that the evidence on the whole is equally in favor of an alternative hypothesis, that these ancient sediments are a part of the older complex which underlies the Huronian, and are pre-Huronian in age.

THE ORDER OF CRYSTALLIZATION IN IGNEOUS ROCKS

N. L. BOWEN
Geophysical Laboratory, Washington, D.C.

A recent paper in this journal by Mr. Victor Ziegler[1] takes the form of a criticism of a paper by Bowen on the order of crystallization in igneous rocks.

Ziegler does not question the statement of Bowen that "the observation of all the relations of outline of a number of minerals in a section of a holocrystalline granular rock leads to a safe conclusion only as to the order in which the minerals have ceased to crystallize." The fact that there is agreement on this point is worth noting.

Ziegler does, however, believe that this order of cessation of crystallization must be also the order of beginning of crystallization. He says, "the order of cessation of crystallization gives a definite clue to the order of beginning of crystallization," although he himself has discussed the crystallization of three-component metal systems in which the final crystallization always consists in the simultaneous formation of three solid phases (simultaneous cessation of crystallization), whatever difference there may be in the order of beginning of crystallization which varies with the relative proportions. Clearly in those systems the cessation of crystallization gives no clue to the beginning.

Bowen in the original paper clearly recognized that if the crystallization of a rock magma is analogous to that of the simple chemical systems that have been studied, the final crystallization should consist in the formation of a number of solid phases (polycomponent eutectic) and that there would be no *order* of cessation of crystallization. It was suggested that the complications which follow from the prevalence of solid solutions among the components of rock magmas might, however, give a result which need not be analogous

[1] *Jour. Geol.*, XXI, 1913, p. 181.

to simple systems. Ziegler discusses two three-component systems in which there is no solid solution and points out that "there is no recurrence of the substance first crystallized in either case. If substances are capable of forming solid solutions they do not affect the above in any way." Yet Vogt,[1] following Schreinemakers has shown beyond doubt that, even in relatively simple systems, solid solution may bring about precisely the result denied it by Ziegler, viz. recurrent crystallization.

In many respects it is entirely unsafe to fall back on analogy with simple systems. The average igneous rock is far from a simple system, neither was it formed under simple conditions. In the finally crystallized product important quantities of borates, fluorides, chlorides, water, CO_2, etc., are not represented. The early portion of the crystallization of a rock magma (the beginning of crystallization) is undoubtedly due chiefly to the cooling-down of the magma, whereas the addition of the final layers to the crystals (cessation of crystallization) may be, *in part*, due to a process which approaches an evaporation during which the above volatile substances are removed. The complications are such that it is entirely unsafe to extrapolate from simple systems investigated under simple conditions.

For this reason Bowen, in the original paper, avoided theoretical discussion, since it must necessarily be on the basis of such extrapolation, and turned to the evidence of the rocks themselves. Thus, certain conclusions were arrived at concerning the order of beginning of crystallization based on the consideration of volcanic rocks as the quenched equivalents of plutonic rocks. Ziegler doubts whether this method is justifiable and points out that the difference of conditions under which volcanic and plutonic rocks crystallize, taking the specific cases of granite and rhyolite, might, theoretically, bring about a different order of crystallization. Certainly, if theoretical considerations were all the light on the subject available, the question would have to remain in this condition of doubt, but there exists other evidence. In nature, rocks occur which have been formed under every conceivable gradation of conditions intermediate between those characteristic of the

[1] *T.M.P.M.*, XXVII, 141–55.

formation of granite and of rhyolite. The rocks formed under these intermediate conditions confirm the evidence of the rhyolites as to the order of beginning of crystallization as Bowen has pointed out. There is not only no evidence that the difference of conditions brings about a reversal in order of crystallization but there is definite positive evidence that no such drastic change occurs.

In view of the fact that the objections of Ziegler are almost entirely the outcome of theoretical considerations which it is dangerous to extend to such complicated systems, and that the evidence of the rocks themselves, on which Bowen based his conclusions, is not questioned, it does not appear that the objections offered seriously impair the conclusions reached by Bowen.

A knowledge of the order of beginning of crystallization is important for the elucidation of the differentiation of rock magmas. Differentiation is not uncommonly discussed in terms of the assumption that ferromagnesian minerals are minerals of early crystallization whether they are present to the extent of 70 per cent or of only 5 per cent. This assumption is often quite obviously at variance with the evidence of the porphyritic facies of the rock types described, and in such cases leads, of course, to erroneous conclusions.

PSEUDOBRECCIATION IN ORDOVICIAN LIMESTONES IN MANITOBA

R. C. WALLACE
University of Manitoba, Winnipeg

THE ORDOVICIAN IN MANITOBA

The Ordovician in Manitoba, as determined by Dowling,[1] consists of the following series in ascending order: (1) The Winnipeg sandstones, directly overlying the eroded surface of the pre-Cambrian. This division consists of beds of soft, often very white, friable sandstones, about 100 ft. thick, containing only a few fossils. The St. Peter sandstone of Minnesota is similar in petrological aspect, but the absence of true Chazy fossils in the Winnipeg sandstone procludes definite correlation with the St. Peter sandstone. The fossils rather suggest upper beds of the Black River, but this formation is in Minnesota represented by shales. (2) The Lower Mottled limestone, exposed along the west side of Lake Winnipeg, and on some of the islands. This formation is about 70 ft. thick. The character of the limestone is very similar to that to be described in detail as the Upper Mottled limestone. It is mottled buff and greyish white, is highly fossiliferous, and shows what are probably fucoidal tracings on the bedding planes. The upper beds are highly charged with siliceous material. (3) The Cat Head limestone, yellow dolomites, even grained and as a rule fine grained, containing cherty concretions which in many instances exceed a foot in diameter. The beds have been estimated to be 68 ft. thick. The large cephalopods which are so common in the Lower Mottled are wanting in the Cat Head series. (4) The Upper Mottled limestone, exposed at several points on the western shores of the northern extension of Lake Winnipeg; also along the Red River, and at the time of Dowling's work more particularly at East Selkirk. Today the limestone quarries of Tyndall provide very good sections of this limestone. The thick-

[1] Geological Survey of Canada, *Annual Report*, 1900.

ness of the division is about 130 ft. Like the Lower Mottled, this limestone is highly fossiliferous, and is characterized by the presence of fossils of large dimensions: various orthoceratites, *Maclurea manitobensis* and *Receptaculites oweni* are particularly abundant. The mottled character of the stone will be subsequently described in detail. The chief difference that has been noted between this and the Lower Mottled is that frequently the pale-colored areas of the Upper Mottled are chalky in character, and readily soil the fingers, a feature not observed in the Lower Mottled. (5) The Stony Mountain formation, a series of ochreous shales overlaid by massive dolomitized limestones, showing a maximum thickness for the whole series of 110 ft. The beds thin out northward. The shales at the base are highly fossiliferous, and probably represent the Utica shales of the Cincinnati group. The top beds of the Ordovician in Manitoba are overlaid, presumably conformably, by the thin-bedded, dolomited limestone of the Niagara formation, exposed at Stonewall and at the mouth of the Saskatchewan River.

Further detailed work is required before an exact correlation of these beds with the Ordovician of Minnesota, Wisconsin, and Iowa can be given. Pending this, the following alternative correlation is submitted, the latter of which seems with the present evidence the more probable.

Minnesota, Wisconsin, and Iowa	Manitoba	Minnesota, Wisconsin, and Iowa
Maquoketa shale	Stony Mountain form (190 ft.)	Maquoketa shale
Galena dolomite	Trenton: Upper Mottled limestone (130 ft.)	Galena dolomite
	Trenton: Cat Head limestone (70 ft.)	Green shales (Black River)
Green shales (Black River)	Trenton: Lower Mottled limestone (70 ft.)	Plattville limestone
Plattville limestone St. Peter sandstone	Winnipeg sandstone (100 ft.)	St. Peter sandstone

THE MOTTLING OF THE LIMESTONE

The quarries at Tyndall furnish good exposures of the Upper Mottled limestone. The following description applies more particularly to what was formerly known as Garson's quarry, now under

the management of the Northwest Quarries Co. Ltd. The surface capping of drift is 8–10 ft. thick, and the bowlders are mainly limestone, very few Archaean granites or gneisses being found. Underlying the drift are thinly and irregularly bedded limestones, 3 ft. thick, mottled in similar fashion to the more massive limestones underneath. Then follow 14 ft. of buff mottled limestone, wrought in ledges 3–6 ft. thick (Fig. 1). This is practically homogeneous,

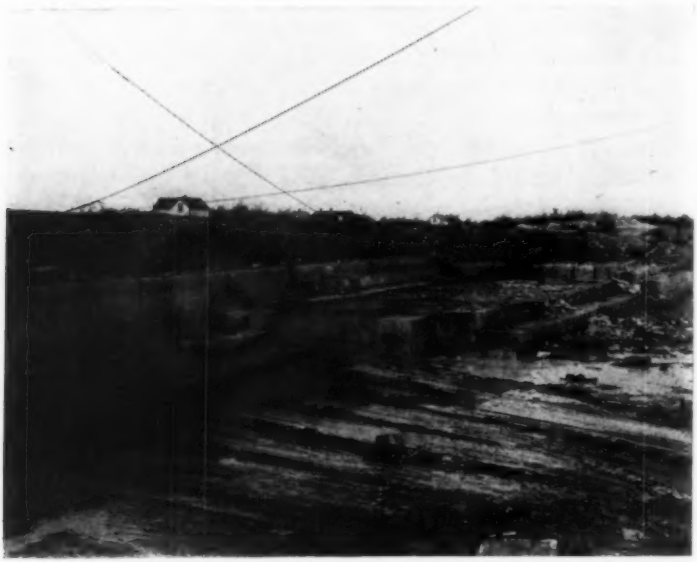

FIG. 1.—Upper Mottled limestone, Garson's Quarry. Tyndall

though certain horizons show the presence of cephalopods more markedly than others (see Fig. 2). Underneath is a blue mottled limestone, uncovered for 6 ft., the darker patches on the stone showing, even on the weathered surface, a darker blue color than on the buff stone. A bore has recently been sunk in order to determine the quality of the underlying strata, and the manager of the quarry, Mr. Pfeiffer, has kindly supplied the following details. The blue mottled is altogether about 13 ft. thick. Underneath this lies a second horizon of buff mottled stone. The quarry and

bore together expose 97 ft. of stone, the lower 62 ft. of which is buff, and so thinly bedded as to be valueless as a dimension stone. In this is found, at a depth of 51 ft. below the top of the limestone in this exposure, a bed 16 ft. thick which might be described as a very impure limestone, high in argillaceous material.

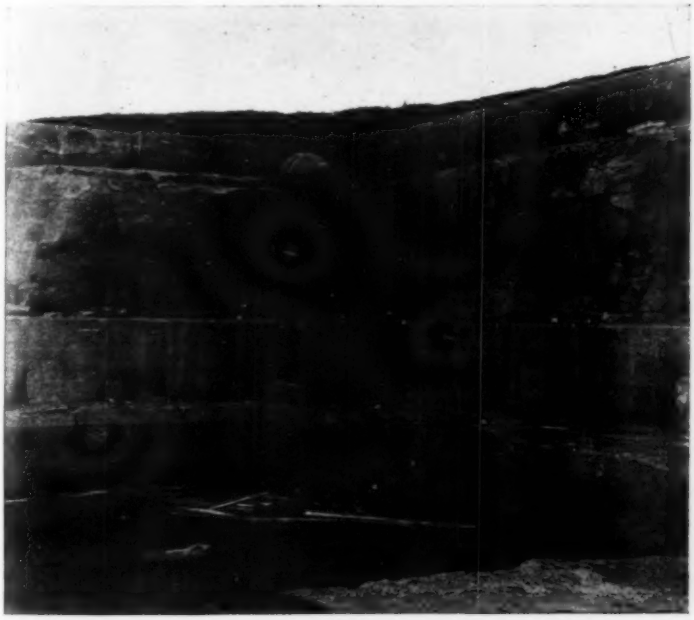

FIG. 2.—Upper Mottled limestone, Henry's Quarry. Tyndall

The rock consists of a light-grey limestone, with patches of darker material scattered through the stone. Though these darker areas are distributed apparently quite irregularly, slabs cut parallel and perpendicular to the bedding planes show that the linear extension of the patches is decidedly along the bedding planes. A comparison of the side of the slab shown in Fig. 3 (cut along the bedding plane) with its end section will be convincing. There is no evidence, on the other hand, of greater development of the darker areas along jointing planes than in any other vertical direc-

tion. The patches, when seen along the bedding planes, have a certain linear development, suggesting branching structures rather than concretionary arrangements. Vertical sections are, however, more commonly roughly circular. The cross-sections are usually not more than 1½ in. in diameter, while along the bedding planes irregularly extended areas 5–6 in. in length are not uncommon.

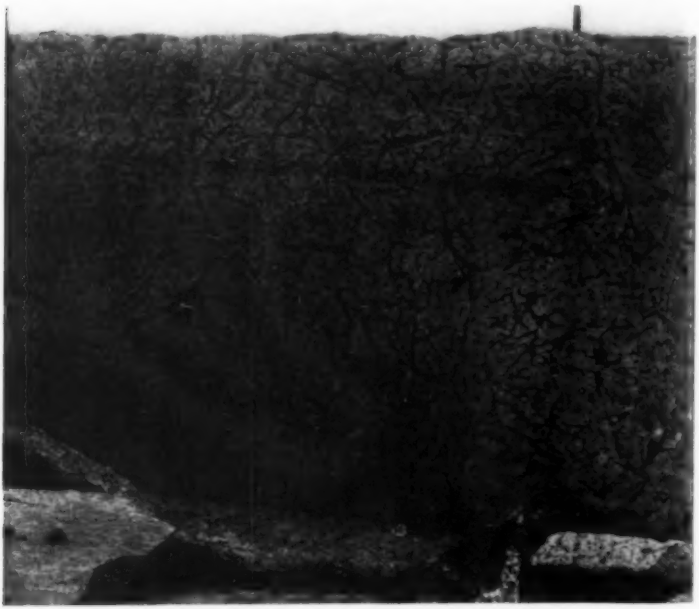

FIG. 3.—Slab of limestone, cut parallel to bedding plane

What are apparently fucoidal traces have been noted on the bedding planes of both the Upper and Lower Mottled limestone. This may have suggested the only explanation that has been offered as to the origin of the mottling of the stone in this district—that given by Panton:[1]

> It [the limestone at East Selkirk] presents a peculiar mottled-like appearance, which adds much to its beauty as an ornamental stone. This strange mixture of brown and white is difficult to account for. In some cases it appears

[1] *Trans. 15 Man. Hist. and Scient. Soc.*, Winnipeg, 1884.

as if the origin might be due to seaweed remains. Often the colored portion approaches the color of yellow ochre, and seems strongly impregnated with iron, while the intervening spaces are more or less colored.

Later work on the Galena and Trenton of Iowa by Leonard[1] has shown that the Galena, which is considered to be a dolomitized phase of the Trenton, is found to grade into the underlying Trenton through strata which possess a somewhat similar mottled appearance to those already described. An analysis showed that the darker areas were dolomitized, while the lighter were unaffected by the magnesia-bearing waters. This was inferred from the chemical analyses for $MgCO_3$ and $CaCO_3$ which were as follows: grey portion, 97.46 per cent $CaCo_3$, 4.31 per cent $MgCO_3$; buff portion, 60.97 per cent $CaCO_3$, 18.28 per cent $MgCO_3$ (*op. cit.*, p. 259). It was also suggested that jointing planes and the spaces between the larger fossils and the surrounding limestone might have served as chambers of passage for the waters which effected the dolomitization. It was observed that although the fossils were not themselves affected, they were frequently surrounded by a dolomitized area.

Under the microscope the difference in structure between the two areas is very apparent (Fig. 5). The darker-colored patches are evenly crystallized, showing sections of rhombohedra of dolomite, set close together, and occasional crystals of hematite passing over into limonite. The color is due to the hematite and, more particularly, the limonite, to which the action of percolating water has imparted a banded structure. Excepting a few large shells, which have not been affected, there are no traces of organic remains in the dolomitized areas (see Fig. 4). The light-colored areas, on the other hand, contain numerous fragments of brachiopod shells, with occasional sections of polyzoa and corals. These are set in a fine-grained calcitic material, strikingly different, even at the margin between the two areas, from the fairly perfectly crystallized dolomite. No hematite or limonite occurs in the lighter material except where occasional local dolomitization has taken place, and there the rhombohedra are always colored by the iron ore. That this is actually a case of pseudobrecciation, and not a

[1] "Geology of Clayton County," *Iowa Geological Survey*, XVI, 259.

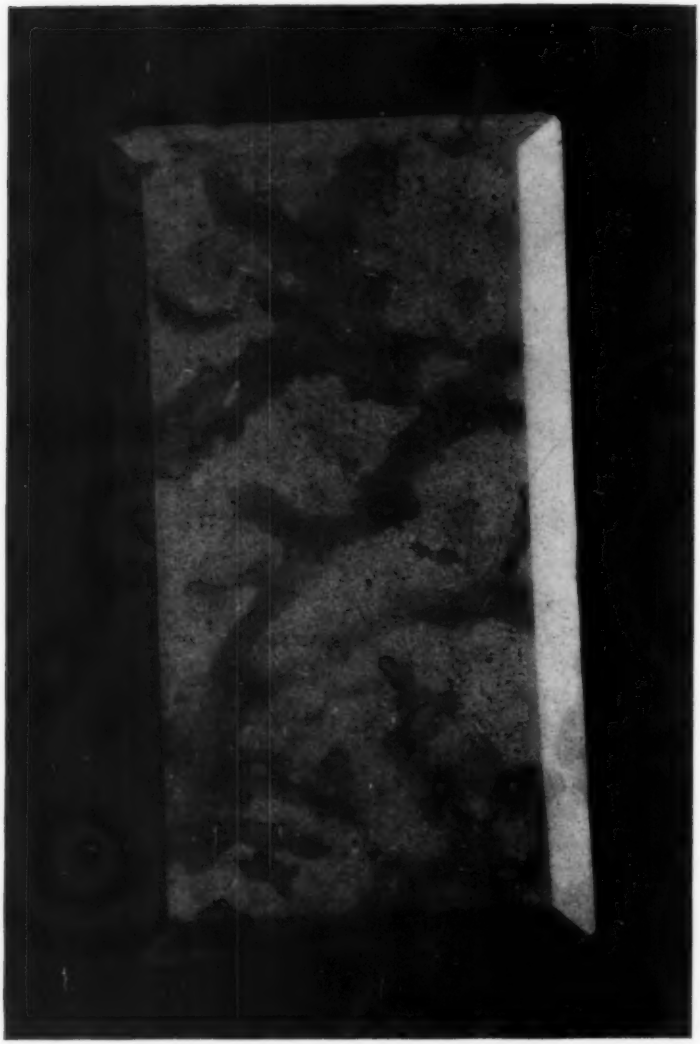

FIG. 4.—Polished surface of the limestone

brecciated structure due to the cementation of a dolomite breccia in a calcareous matrix, is evident from the microscopical examina-

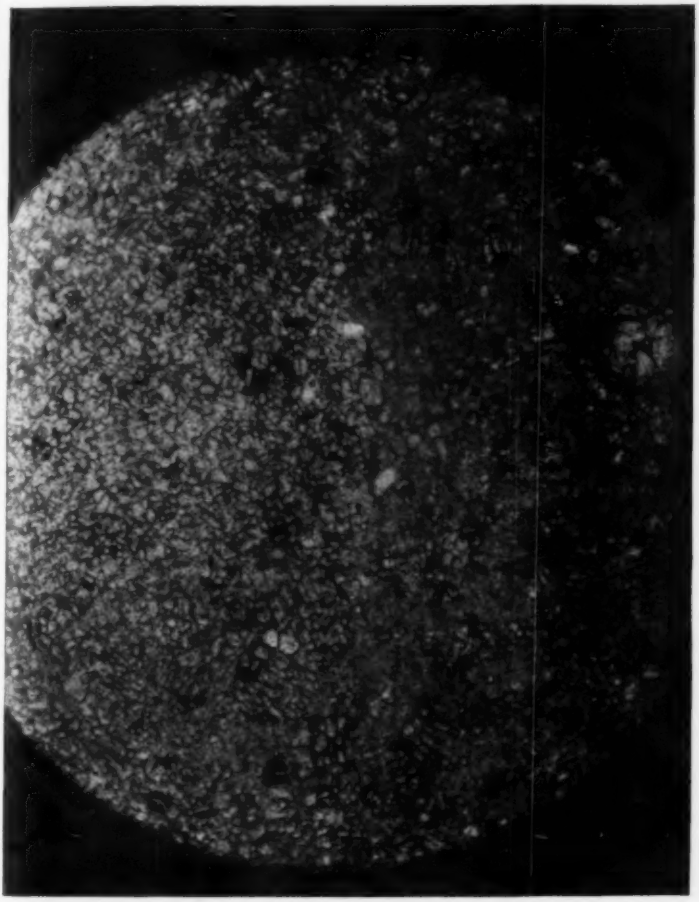

FIG. 5.—Thin section, showing margin between dolomitized (left) and undolomitized (right) limestone. ×31.

tion. In several thin sections there are found at the margins of the dolomitized areas fossils which have been surrounded by a thin

strip of dolomitic material—the dolomitization having ceased when the percolating waters met round the shell. That breccia of such a type could have existed without the fossils becoming detached is hardly possible. A study of the margin of the darker areas leaves no doubt that we are dealing with a secondary dolomitization. Although there is a definite marginal line, it shows so sharp interpenetration of dolomitized and undolomitized material that it could have been caused only by the irregular advance of waters bearing magnesian salts in solution.

Microscopic investigation shows that the hematite, which with the limonite is responsible for the color effect of the darker patches, is found in crystals separate from the dolomite, and at the edges of the dolomite rhombohedra. The dolomite is itself clear and colorless; and the position of the hematite crystals, and their invariable association with dolomitic areas suggest naturally that the hematite was formed by the same agency that gave rise to the dolomitization. From the microscopic evidence alone, the most feasible explanation seemed to be that during the process of dolomitization the ferruginous material, originally present in the form of ferrous carbonate as an isomorphous admixture with the calcitic material, had to a large extent separated out owing to the greater inability of the dolomite to hold the iron isomorphously. Once separated as carbonate, the iron would undergo oxidation much more rapidly than is possible in a mixed crystal where the calcite exercises a controlling influence, retaining the iron in the ferrous state. A chemical analysis should then show—if this theory can be supported—that although the darker areas are richer in magnesia and in ferric iron, and the lighter areas contain practically no magnesia, the total iron is approximately the same in both.

CHEMICAL INVESTIGATION

The two varieties were separated as completely as possible, and subjected to chemical analysis. The calcium was estimated volumetrically, the magnesium gravimetrically. The total iron is given here as Fe_2O_3. The iron precipitate was dissolved and reduced by zinc, and the iron estimated volumetrically. The ferrous iron was estimated volumetrically in a separate portion.

The following may be taken as representative of several sets of analyses.

	Light Colored	Dark Colored
SiO_2	1.56 per cent	1.56 per cent
Total iron, as Fe_2O_3	0.16	1.94
(FeO	0.12	0.45)
Al_2O_3	0.06	2.27
$CaCO_3$	94.02	71.03
$MgCO_3$	4.33	23.35
Total	100.13	100.15

The analyses show that nearly all the iron and alumina have been introduced with the Mg-bearing waters. The theory outlined above is consequently untenable. It may also be pointed out here that while in the light-colored limestone, where the ratio of the $MgCO_3$ to $CaCO_3$ is approximately 1:22, no recrystallization has taken place, in the darker stone, where the proportion is roughly 1:3, "dolomitization" has taken place, though the proportion required in a true dolomite is 1:1. This point will be again referred to in the discussion of the origin of the "dolomitization."

THE ORIGIN OF THE MOTTLING

If we exclude true brecciation as an explanation of the mottled effect of these limestones, there remains only one or other of two possibilities. Either the dolomitization has taken place practically simultaneously with the formation of the limestone, or subsequent dolomitization has ensued by water infiltration after a great thickness of the limestone has been laid down, and consolidation has taken place. Dixon, who has made a study of the dolomitization of the Carboniferous limestone of South Wales,[1] remarks on the difference between contemporaneous and subsequent dolomitization. He considers that subsequent or vein dolomitization is characterized by (*a*) larger average size and greater clearness of the rhombohedra, (*b*) inclusions of hematite, (*c*) association of dolomitization with calcification, (*d*) preference of dolomitization

[1] *Quart. Jour. Geol. Soc.*, XVII (1911), 477; and *Geology of South Wales Coalfields*, VIII (1907), 15 ("Memoirs Geol. Survey").

for oöliths and corals. In the case of vein dolomitization, calcification usually precedes dolomitization, the softer, abraded material being first attacked by water and recrystallized, while the Mg-bearing waters subsequently attack what has not been affected. Thus the parts that are affected by the Mg-bearing waters in subsequent dolomitization are just such as contemporaneous dolomitization would not affect—oöliths, corals, etc., the hardest parts in ordinary sediments but the softest in the recalcified rock. Judged by Dixon's tests, the pseudobrecciation of the Manitoba limestones is contemporaneous. There is no secondary calcification, the harder shells of corals, brachiopods, etc., have not been attacked in preference to the matrix, and the hematite is not included in the dolomite crystals. It seems difficult to imagine how subsequent dolomitization could affect a limestone in such a way that throughout a thickness of almost a hundred feet a uniform mottling should be produced, the affected areas being unconnected vertically. Leonard[1] seems to favor the view that the dolomitization in Clayton County is a subsequent phenomenon, in the sense that it was probably contemporaneous with the dolomitization of the Galena. This was inferred from the fact that the mottled limestones were found separating the fully dolomitized Galena from the underlying undolomitized Trenton in all cases except where impervious shales formed a sharp boundary line between the uniformly dolomitized and the non-dolomitized strata. The actual conditions are, however, different in Manitoba. Both the Lower Mottled and Upper Mottled limestones are overlaid by more completely dolomitized horizons—the Cat Head and the Stony Mountain formations—but a gradation from a mottled stone to a grey undolomitized limestone has nowhere been observed; nor can it be said that there is in any measure a gradation from a sparingly dolomitized variety by regular stages into a typical dolomite. The proportion of darker material is as great at the base of a section of mottled limestone 97 ft. thick as it is at the top.

CONTEMPORANEOUS DOLOMITIZATION

The evidence goes to show that the dolomitization in this area took place more probably as a practically contemporaneous

[1] *Loc. cit.*

phenomenon when the calcareous mud was as yet only partially solidified. We have then to account for the selective dolomitization of the calcareous ooze. Dolomite is formed according to the following reversible reaction:

$$2CaCO_3+MgCl_2=CaCO_3\cdot MgCO_3+CaCl_2$$

and the action is found to proceed from left to right when a temperature of 100° C. is reached. Increase of temperature accelerates the action. It is well known, however, that dolomitization has taken place, and is taking place today, where the proportion of Mg salt to Ca salt is much below that represented by the above equation. The process that goes on in nature is perhaps more accurately represented, as Klement has suggested,[1] by a continuous readjustment of equilibrium between the solution pressure of the solid $CaCO_3$ and the pressure of the Mg ions out of solution. Dolomitization would then ensue after the $CaCO_3$ had been precipitated; or, more correctly, a transformation takes place by which crystals of the optical characters of dolomite are formed, though the percentage of $MgCO_3$ may be smaller than that required for a true dolomite. In other words, dolomite is seemingly capable of forming mixed crystals—up to a certain limit—with $MgCO_3$, a substance not strictly isomorphous with itself. If then the reaction be stated crudely as $Mg'' \rightleftharpoons Ca$, as an abbreviation for the statement that the two reactions $Mg'' \rightleftharpoons Mg$ and $Ca \rightleftharpoons Ca''$ are not independent, but regulate each other, three factors would affect the equilibrium: (1) percentage of Mg'' in the sea water, (2) temperature of the water, (3) character, though not of course the quantity, of the $CaCO_3$. An increase of Mg ions, and increase of temperature move the equilibrium point from left to right; while $CaCO_3$ in the form of aragonite is more readily affected, especially at moderately high temperatures, than is calcite, presumably because of the greater solution pressure of the $CaCO_3$ in the aragonite modification. In seeking for an explanation of selective dolomitization in the Manitoba limestones, one may practically discard the second and third factors. Local temperature changes may be neglected, except in so far as taken into account in a hypothesis outlined below, and there is no indication that aragonite shells have been attacked.

[1] *Tscherm. Min. Petr. Mitteil.*, XIV (1895), 530.

The proportion of Mg salts in ordinary sea water is very small (0.12–0.15 per cent Mg, increasing slightly with the depth). In inland seas, exposed to excessive evaporation, it may rise to 4.15 per cent Mg, as in the Dead Sea at 300 meters depth. Such exceptional conditions could not have prevailed; indications point to a clear, rather shallow sea, with recurrent periods of slight sedimentation. It may well be, however, as indicated by Steidtmann,[1] that the seas of the early Palaeozoic contained a slightly greater proportion of Mg salts than do similarly situated seas of today. The proportion of $MgCO_3$ in the paler-colored limestones shown by the analyses represents the amount of $MgCO_3$ that was deposited under normal conditions in these seas. It may be taken as the solid phase in equilibrium with the Ca and Mg salts in solution at that particular temperature and pressure, though undoubtedly a small proportion of the $MgCO_3$ was originally introduced as an ingredient in the composition of the calcareous shells. No recrystallization, and consequently no dolomitization in the strict sense of the word, has taken place. Presumably the $MgCO_3$ exists in solid solution with the very fine-grained calcitic material in which the broken shells are imbedded.

It would appear, then, that the dolomitization (with recrystallization) of the darker areas was due to the presence locally of a larger percentage of Mg salts than the normal. From this point of view three suggestions as to the cause of the dolomitization might be examined: (1) that algae, either as attached fucoids or as unicellular algae of the plankton, had contributed the necessary salts; (2) that the markings are due to worm castings; (3) that sea water inclosed in cavities, such as the interiors of shells, had dolomitized the neighboring rock.

The last of these suggestions we may consider first. Occasionally large shells are found in the center of the dolomitized areas, while no other trace of organic remains is to be found. If sea water replaced the softer parts of the organisms on their dissolution, and was retained till the layers were buried under a gradually hardening ooze, the slight rise in temperature and pressure might be sufficient, where undisturbed contact between the solid and

[1] *Jour. Geol.*, XIX (1911), 323.

liquid phases was preserved over a long period, to effect a gradual dolomitization. A concentration of magnesium salts in such a case is hardly possible, as evaporation could not have taken place; the result must be attributed entirely to long-continued favorable physical conditions. This is the explanation that first suggested itself; but it is hardly tenable. If such a process does actually take place, it is difficult to see why it should be the exception rather than the rule, as the possibility of inclusion of sea water in fossiliferous limestone, owing to the decomposition of the softer parts of the organisms, would always be fairly great.

Tracings of *Serpulites dissolutus* and of *Arabellites* sp. undet. have been identified in the limestones of the Lower Mottled division. It might naturally be suggested that the mottled effect in the limestones is due to actual castings of annelids, or to subsequent infillings of their borings. A well-known instance of the preservation, on a large scale, of annelid borings is that shown in the Middle and Upper Cambrian of the northwest Highlands of Scotland. In the Serpulite Grits and so-called "Fucoidal" beds, large trumpet-shaped depressions are found on the surface, which lead downward into vertical, cylindrical tube structures, much constricted in places. These are without much doubt the castings of annelids, the sudden constrictions and widenings representing the peristaltic movements of the intestines. Overlying these beds, limestones and dolomites 1,500 ft. thick are found, consisting in part of mottled beds (the "mottled" or "Leopard" stone of the Sailmohr group). Throughout the whole series fossils are rare, and the limestones, which contain numerous cherts, are attributed to the calcareous and siliceous remains of the plankton. The mottling of the limestone is due to the fact that the worm castings are dolomitized, and darker than the rest of the stone. According to Peach,[1] an explanation might be sought in the assumption either that the annelids were selective in their food, or that their gastric juices predisposed to dolomitization.

On contrasting the markings of the Upper Mottled with these, one finds two points of difference. In the limestones under discussion the markings are horizontally elongated, and irregular;

[1] Peach and Horne, and others, *The Northwest Highlands of Scotland*, p. 380.

in the Sailmohr the markings are vertical, rectilinear, and well defined. From the position and character of the markings, one may discard the theory that they are due to castings, which would in most cases be vertically disposed or grouped round definite centers. If taken simply as tracings, the difficulty in explaining the dolomitization still remains, and one is thrown back again on some such theory as the inclusion of water in the cavities left by the annelids. Although local dolomitization and mottling in limestone may in certain cases be attributed to annelids, one can hardly consider that markings of the kind found in the mottled limestones of Manitoba are due to this cause.

There remains the hypothesis that the mottling is connected with algic decomposition. Analyses due to Goedechens[1] show that the percentage of MgO in the ash of algae collected from the west coast of Scotland may reach 11.66. If then the algae of the sea bottom become buried under a thin coating of calcareous ooze before actual decomposition ensued, the liberated Mg salts might, in conjunction with the sea water of fairly high Mg content, cause such increase of Mg ions locally as to give rise to actual dolomitization. Only from such organisms and allied types could the percentage of Mg salts be increased locally to any appreciable extent. There are certain structural features of the markings that lend some support to this view of the origin of the dolomitization. They are horizontally placed, are markedly dendritic, and the sections often show a darker core which might represent the actual position of the plant; while the magnesian waters, extending outward from this central nucleus, have affected the surrounding stone. Again, thin sections of the dolomitized areas occasionally show a narrow central tube of clear, well-crystallized calcite (see Fig. 6), indicating that a cavity had existed when the dolomitization took place, and that this was subsequently infilled with calcite. Such cavities might be formed when, owing to decomposition, the organism disappeared. The hematite and limonite of the recrystallized dolomitic material would be attributed to the iron salts of the algae. Fig. 7 shows a normal cross-section, where no subsequent infilling has taken place.

[1] Pfeffer, *Pflanzenphysiologie*, I, 110.

Some of the difficulties in the way of the hypothesis may be referred to. A sea bottom in which a calcareous mud is gradually

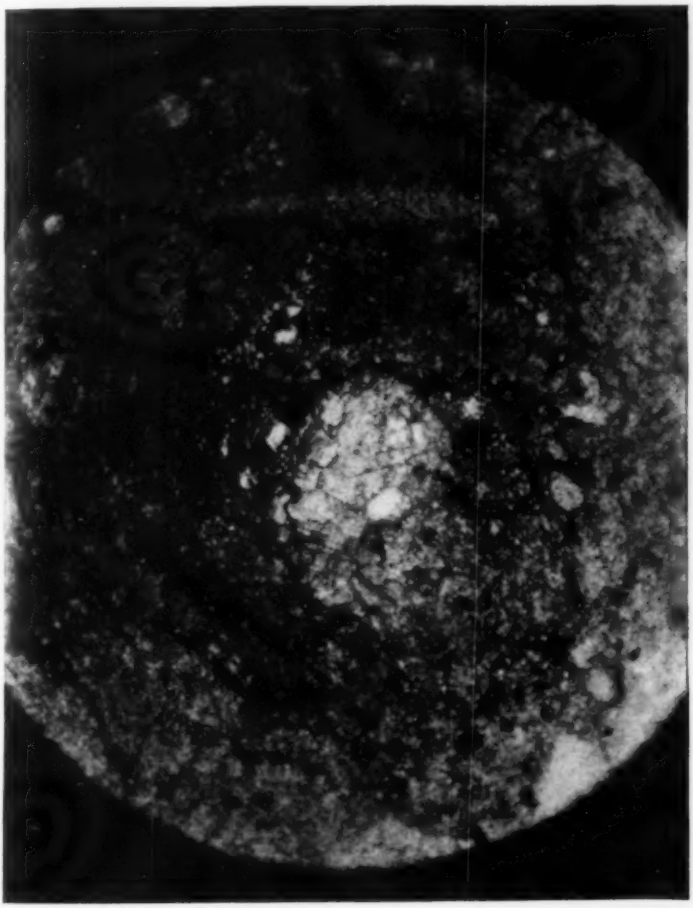

FIG. 6.—Dolomitized area with core of calcite. Border undolomitized. ×31

accumulating would not provide the rocky bottom necessary for algae in any way comparable to the laminaria of our seas; and a

profusion of vegetable growth would presumably be possible only in the shallower waters nearer shore. In the pre-Devonian rocks,

FIG. 7.—Section showing dolomitized area (center of field). ×31

definite impressions of fucoids are rare, though "fucoidal traces" have been the *dernier ressort* in cases of difficulty.[1] Unless when

[1] Seward, *Fossil Plants*, I, 139.

protected by a calcareous sheath, algae could be preserved only under exceptional conditions. We have, then, no definite knowledge of the development of attached algae in Ordovician and Silurian seas. In the strata in question, indisputable fucoids have been obtained only from the Cat Head and Stony Mountain beds, which are nowhere mottled, and are uniformly dolomitized. They are found as imperfect markings, and generally as raised impressions, and have been referred by Whiteaves to five distinct species of *Chondrites*.[1] Numerous unidentified markings on the bedding planes of the limestones have also been ascribed to fucoids.

If one may judge from the amount of carbonaceous material in rocks prior to Silurian times, it is probable that the algae had already attained a widespread development. The conditions which would give rise to dolomitization from plant forms which are so widespread in later seas must of course have been exceptional, and the chemical constitution of the seas of the period may provide the best explanation for the phenomenon. The evidence that has elsewhere been collected[2] goes to show that the percentage of magnesium salts in the early Palaeozoic seas was distinctly higher than in the ocean today. In the seas in which the Lower and Upper Mottled were laid down it was not sufficiently high to cause dolomitization in the sense that actual crystals with the optical properties of dolomite were produced; but the addition of magnesium salts from the decomposing algae was all that was required to start the process. Changing physical conditions—probably a shallowing of the sea—increased the Mg content at the time when the Cat Head and Stony Mountain formations respectively were being deposited, and in these formations a uniform, though by no means complete, dolomitization was effected. The algae may have drifted seaward from the rocky shores, and may have been fairly rapidly silted over. It is worthy of note that the presence of unicellular algae of the plankton has been confirmed in rocks of similar age in Wisconsin, and has been referred to, as already indicated, in the limestones of the upper Cambrian in the northwest Highlands of Scotland. The "oil rock" in the Galena of Wisconsin is found

[1] Geological Survey of Canada, *Palaeozoic Fossils*, III, Pts. 1 and 2.

[2] Steidtmann, *loc. cit.*

on microscopical examination to contain very numerous oval yellow bodies, which are interpreted by White[1] to be unicellular gelosic algae, probably comparable to the living Protococcales. The precipitation of the well-known lead and zinc deposits of this formation is attributed by Bain[2] to the reducing action of the hydrocarbons, and probably to hydrogen sulphide, resulting from the partial decomposition of the algae. Whether in the Manitoba limestones the mottling may be accounted for in part by unicellular algae settling in local depressions on the sea floor—caused for instance by the burrowings of annelids or other animals in the silt—the writer is not prepared to say. After reviewing, however, the hypotheses which may be advanced to account for a phenomenon the origin of which it is difficult indeed precisely to define, he is compelled to conclude that the evidence is strongly in favor of the theory that the decomposition of algae has been primarily responsible for the local dolomitization which is so marked a feature of these limestones.

SUMMARY

The irregular mottling which is a characteristic feature of two horizons of the Ordovician limestones in Manitoba is due to the presence of certain dolomitic areas in the limestone. The color contrast is caused by hematite and limonite filling the interstices between the dolomite crystals, rendering the affected areas much darker than the non-dolomitic.

The apparently brecciated structure is not truly clastic. The darker areas have been dolomitized *in situ* by Mg-bearing waters, working from the center outward.

Chemical analyses show that the iron salts have been carried in the waters which affected the transformation, and the iron minerals are not, as might be supposed from microscopical investigation, the result of the oxidation, when recrystallization took place, of ferrous carbonate held isomorphously in the calcitic material of the limestone.

The evidence in the field and laboratory is sufficiently convincing to lead one to conclude that the dolomitization is not a subse-

[1] *Wisconsin Geol. and Nat. Hist. Soc.*, XIX, 26.

[2] *Ibid.*, 142.

quent phenomenon—due to the percolation of Mg-bearing waters from above through considerable thicknesses of limestone along lines of weakness, but took place as a practically contemporaneous process with the formation of the limestone, in the upper layers of the calcareous ooze of the sea bottom.

A limestone may undergo uniform dolomitization when the percentage of Mg ions in the sea water affecting it is much smaller than the chemical equations usually taken to represent the process would demand. The percentage of Mg ions in the seas in which the Lower and Upper Mottled limestones in Manitoba were laid down was probably considerably higher than that in the sea today, but lower than that necessary to cause dolomitization such as the darker areas have undergone.

Under such conditions three factors would tend to produce local dolomitization: (1) local rise in temperature, (2) presence of aragonite in the calcareous ooze, (3) a greater percentage of Mg ions in the water permeating certain parts of the hardening ooze. The last factor is the preponderating one in the area under investigation.

Three suggestions are considered as possible explanations of the irregular dolomitization: (1) sea water included in the shells, replacing the decomposed softer parts of gasteropods, etc., has in time affected the surrounding rock; (2) the castings of annelids have become dolomitized in preference to the surrounding rock; (3) the limestone immediately surrounding decomposing algae has been dolomitized, the magnesium salts liberated from the algae being sufficient to raise the percentage of Mg ions in the sea water so far that recrystallization could take place.

The writer considers the third suggestion that which best explains the facts of the case. How far the effect is to be attributed to fucoids, and how far to unicellular algae of the plankton, one cannot definitely ascertain; but fucoids probably played by far the main part in contributing the necessary magnesian salts.

VARIATIONS OF GLACIERS. XVII[1]

HARRY FIELDING REID
Johns Hopkins University, Baltimore, Maryland

The following is a summary of the *Sixteenth Annual Report* of the International Committee on Glaciers.[2]

THE REPORT OF GLACIERS FOR 1910

Swiss Alps.—The summer of 1910 was extremely wet and snowy, which interfered materially with the measures of the glaciers; nevertheless it was found that the retreat is still general, although it is becoming less and less marked. Of the fifty-four glaciers measured, only two are actually advancing, namely the Sex Rouge and the Lower Grindelwald; some others show indications of possible advance; all in this class lie north of the Rhone and Rhine valleys.

Eastern Alps.—In this region also the wet summer interfered with observations. Two glaciers, in addition to the one mentioned last year, are advancing. In general, the glaciers are in retreat. Many ice avalanches fell in a part of the Oetztal, which was formerly free of ice.

Italian Alps.—The retreat here also is general. On account of the heavy snowfall some small glaciers were covered with snow to their ends during the whole summer, so that good observations could not be made. This was especially true of the Lombardy and Venetian Alps.

French Alps.—Many snow gauges have been set up by the French government and they show a decided increase in the snowfall in comparison with the average of the last ten years. At Sixt the snowfall was twice as great as the average. The quantity of snow which has come down in the form of avalanches is also materially greater. Although the glaciers in the *massif* of Mont Blanc, in the Tarentaise, in the Maurienne, and in the Dauphiné are all retreating, they seem to be increasing in thickness at the

[1] Earlier reports appeared in the *Journal of Geology*, III–XIX.

[2] *Zeitschrift für Gletscherkunde*, VI (1911), 81–103.

higher levels; and there is every indication of an approaching advance. The snow fields are increasing in size and vegetation is taking hold on the barren areas below the ends of the glaciers, indicating apparently a more moist climate.

Swedish Alps.—Of the five glaciers reported, all are apparently advancing.

Norwegian Alps.—In Norway a large number of glaciers are measured; during the last year the changes have been mixed, some advancing and some retreating, but an examination of the lists shows that on the whole the changes are distinctly toward an advance.

Africa.—Photographs of Kilimanjaro taken in 1898, 1904, and 1906 show that the glaciers on this volcano are retreating. A photograph taken in 1901 indicated an increased accumulation of snow in the crater, but in spite of this the glaciers are becoming smaller.

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1911[1]

The Hallett Glacier shows no measurable change (Mills).

More snow than usual was found on the Arapahoe Glacier, but the end suffered a slight recession (Henderson).

Eliot Glacier on Mt. Hood continues its retreat (Langille).

Professor U. S. Grant and Mr. D. F. Higgins have continued their descriptions of some Alaskan glaciers.[2] Their latest observations were in 1909. They found that the Yale Glacier occupied about the same position as in 1899; that the Harvard Glacier had advanced a quarter to a half-mile, and the Bryn Mawr Glacier about 500 feet between 1905 and 1909. The position of the Barry Glacier is known for 1899, 1905, 1908, 1909; since 1899 it has retreated about 2 miles, and the rate of retreat seems to be increasing. Between 1905 and 1909 Toboggan Glacier advanced about 400 feet and then retreated about 650 feet. Many other glaciers were photographed

[1] A synopsis of this report will appear in the *Seventeenth Annual Report* of the International Committee. The report on the glaciers of the United States for the year 1910 was given in this *Journal*, XIX, 455–61.

[2] "Glaciers of Prince William Sound, and the Southern Part of the Kenai Peninsula, Alaska," *Bull. Amer. Geog. Soc.* (1910), XLII, 721–38; (1911) XLIII, 321–38, 401–17, 721–37.

and maps made of their ends. In general, where definite information was obtainable the glaciers proved to be in retreat, but some of them appeared to be advancing. Evidence was found of an advance of Columbia Glacier perhaps 50 years ago, and also of an earlier recession. About 1894 there was an advance, followed by a retreat. In 1905 the ice had retreated 160 feet behind its limit in 1899, but had regained 100 feet in 1908. Between July 15, 1908, and August 23, 1909, the ice advanced 380 feet.

Professor Lawrence Martin sends me the following account of the changes in a number of Alaskan glaciers between 1910 and 1911[1]:

Copper River.—The Childs Glacier, which advanced about 1,800 feet between the spring of 1909 and the autumn of 1910, for the most part in the season of 1910, moved forward 97 feet in the following eight months.[2] This movement, measured at the northern margin, where the glacier was only 1,474 feet from the Copper River and Northwestern Railway bridge in 1911, is at a much less rapid rate than during the previous summer, and the Copper River railway bridge is probably safe from the glacier during the closing stages of the present period of spasmodic advance; the river will probably always protect the bridge by undercutting the ice front during periods of rapid advance which come at high water, for the summer volume of the river is about equal to that of the Mississippi. This brief, spasmodic advance of Childs Glacier suggests the earthquake avalanche type seen 190 miles east in Yakutat Bay.

Miles Glacier, whose advance from 1908 to 1910 was 1,800 to 4,000 feet, in different portions of the ice cliff, had nearly ceased its rapid forward movement in June, 1911. The Grinnell Glacier continued during the winter of 1910–11 a slight advance, commenced the summer before. Allen Glacier showed no changes from 1910 to 1911. The Heney Glacier, which was stagnant for a long time before September, 1910, was newly crevassed and beginning to advance in June, 1911.

Southeast of Mt. Wrangell, the Kennicott Glacier, at whose margin a railway has recently been built, is stagnant and inactive, as it has been since before 1898. The Chitistone Glacier, some distance east of the Kennicott, is reported by R. F. McClellan to have advanced about half a mile during the winter of 1910–11.

Alaskan Range.—The Gulkana, Cantwell, Castner, and a large unnamed glacier near Rapids Roadhouse were inactive and retreating in 1911, as they have been for several years.

[1] See also Lawrence Martin, "The National Geographical Society Researches in Alaska," *Nat. Geog. Mag.*, June, 1911.

[2] In the table giving the variations of the Childs Glacier in the last report, "Advance in Feet" should be substituted for "Advance in Meters."

Prince William Sound.—Columbia Glacier, which advanced more than 1,700 feet between 1908 and 1910, has continued a slow forward movement, apparently due to climatic causes. The western margin advanced a little less than 100 feet from September 5, 1910, to June 21, 1911. The Valdez Glacier continued to retreat from 1910 to 1911, the amount of recession from June, 1909, to June, 1911, being reported by the late L. S. Camicia, of Valdez, as 36 feet.

Kenai Peninsula.—Spencer Glacier, close to the Alaska Northern Railway, retreated only 36 feet between January 8, 1906, and June 26, 1911. Glacier streams from this ice tongue have deposited outwash gravels so that twenty trestles in a distance of 1½ miles along the railway were filled and had to be abandoned. An elaborate and successful attempt to divert the glacial streams was carried out while the National Geographic Society party was at Spencer Glacier in June, 1911. As a result of the work of man in blasting a channel in the ice and producing two new subglacial stream courses, this glacier will probably retreat more rapidly in the next few years. Bartlett Glacier near the same railway is inactive and retreating.

Yakutat Bay.—A Boundary Survey party under N. J. Ogilvie visited Yakutat Bay in 1911 and took photographs from a number of sites occupied by Tarr and Martin in previous years. These photographs, furnished through the courtesy of Boundary Commissioner W. F. King, show the following: Nunatak Glacier, which retreated 2½ miles between 1890 and 1909 and advanced 1,000 feet the following year, made a further slight advance by the summer of 1911. The front of Hubbard Glacier had almost the same position in 1910 and 1911. The northern margin of Turner Glacier retreated slightly. The crevasses in Variegated Glacier, which was impassable in 1906, had so far healed by melting that in 1911 the Boundary Survey party traveled up the glacier to its head. Lucia Glacier, which was impassable in 1909, was traversed by the same party in 1911; so was Marvine Glacier, which was impassable in 1906.

Glacier Bay.—Muir Glacier retreated about 2,000 feet between 1907 and August 30, 1911. The thinning of the glacier by ablation and flow is an even more impressive feature than the retreat of the tidal ice front. It was possible, for example, in 1911, to walk upon a beach where, in 1907, there was an ice cliff, and where, in 1892, the ice was 1,200 feet thick. Tree stumps 12 to 18 inches in diameter, uncovered by the melting of the ice, show that the maximum advance of the eighteenth century was preceded by a minimum when Muir Glacier was even more emaciated than in 1911.

Other ice tongues in Glacier Bay which have continued receding are the following: Carroll Glacier had retreated so far that the eastern part of it did not touch the sea at low tide in 1911. A great delta had been built forward from nearly the middle of the ice cliff. Ablation had also removed the western distributary of Cushing Glacier, which previously spilled over to Carroll Glacier. Grand Pacific Glacier is retreating less rapidly than it did between 1899 and 1907, possibly because it is about to cease to be tidal. Johns Hopkins

Glacier is nearly separated into two independent ice tongues. Charpentier and Favorite Glaciers have been dismembered since 1906 by recession. Reid, Hugh Miller, Wood, and Geikie glaciers in Glacier Bay and Brady Glacier in Taylor Bay have changed less rapidly, though they are still receding.

La Perouse Glacier, west of Mt. Fairweather, and 130 miles southeast of Yakutat Bay, changed very little between 1910 and 1911, apparently having had in 1910 a brief spasmodic advance of the earthquake avalanche type.

In contrast with the other ice tongues of Glacier Bay, Rendu and an adjacent unnamed glacier have made notable advances. The former retreated about 2,000 feet between 1892 and 1907; it then advanced at least 8,350 feet and retreated again 600 feet by September, 1911. If the rate of the last retreat was about the same as the earlier one, the whole of the remarkable advance must have taken place in 1907. As Rendu Glacier is only 120 miles southeast of Yakutat Bay where nine or more glaciers have advanced since 1899 in response to earthquake avalanching, its advance may have been due to the same cause, and it will be interesting to see whether any of the other ice tongues of Glacier Bay push forward within the next few years. The small cascading glacier immediately south of Rendu Glacier has advanced a quarter-mile since 1907 and was discharging icebergs in 1911.

Southeastern Alaska.—Rainy Hollow Glacier, northwest of Lynn Canal, advanced more than 2,000 feet between June and September, 1910, as observed by the late Webster Brown. This brief, spasmodic advance in an ice tongue only 120 miles east of Yakutat Bay suggests the earthquake avalanche cause for activity. Davidson Glacier in Lynn Canal is still inactive; it changed little between the visit of G. K. Gilbert in 1899 and that of the National Geographic Society party in 1911. Eagle, Herbert, and Mendenhall glaciers, north of Juneau, which have recently been mapped in detail by the United States Geological Survey, seemed, as seen from a distance in 1911, to have suffered little change in recent years. Taku Glacier continued to retreat from 1907 to 1911. Norris Glacier, which was advancing and destroying vegetation when visited by F. E. and C. W. Wright in 1906, was advancing slightly and overriding shrubs in 1911. None of the ice tongues on the Stikine River displayed signs of abnormal activity in September, 1911. Popoff Glacier has retreated considerably since 1904.

The Kahiltna, Tokichitna, and Little Tokichitna glaciers, on the eastern side of the Alaskan Range, have large trees growing very close to their ends, indicating a stationary or advancing phase (S. R. Capps). But the glaciers on the western side of the range seem to be in retreat (Brooks).[1] About 30 miles east of Cape Yakataga the Malaspina Glacier has receded about 10 miles, leaving a good harbor (H. Horick).

[1] "The Mt. McKinley Region, Alaska," *Professional Paper 70, U.S. Geol. Surv.*, Washington, 1911.

THE EXTENT OF THE CORDILLERAN ICE-SHEET

CHARLES A. STEWART

Through the courtesy of members of the United States Forest Service I was enabled, in the summer of 1912, to make some observations upon glaciation in the Kaniksu National Forest in northern Idaho. Because of the inaccessibility of a part of the region and the lack of suitable maps, the work was not complete; but in view of our slight knowledge of the extent and character of the continental glaciation in the northwestern United States, and because the nature of the country makes it extremely unlikely that it will be more carefully studied in the near future, it seems advisable to publish the facts noted. Moreover, there was discovered evidence of more complete reworking of glacial deposits by stream action than has yet been described.

It is known that the front of the Cordilleran ice-sheet was marked by a series of marginal lobes occupying the north-south intermontane valleys of the northwestern United States. The line of crosses in Fig. 1, based on data published by Professor Salisbury,[1] shows the probable extent of some of these lobes. It is believed that the Pend d'Oreille lobe was continuous with that in the Colville valley, but its connection with the Kootenai lobe was well north of Bonners Ferry, and probably north of the International Boundary. In the paper cited nothing is said of the eastern boundary of the Pend d'Oreille lobe, but my observations show that the ice must have covered the divide between the Pend d'Oreille and Priest Lake valleys.

This divide is a range of forest-covered hills having a maximum elevation of 6,500 feet, and an average height a thousand feet less. The former presence of ice on these hills is unmistakably shown by the rounded topography, by *roches moutonnées*, and by glacial striae—in one instance on bedrock, and in others on float. The striae on bedrock strike N. 10° W. Looking east across Priest

[1] *Jour. Geol.*, IX, 721–24.

Lake from the top of this divide to the eastern shore of the lake, one sees the eastern line of the ice clearly marked. From this shore rises a series of hills with a smoothly rounded topography strongly indicating glaciation, but farther in the background is a higher ridge of granite, with a serrated and pinnacled outline in sharp contrast to the gentler slopes of the lower hills. Closer examination of this divide east of Priest Lake valley discloses a series of cirques worn out by valley glaciers tributary to the

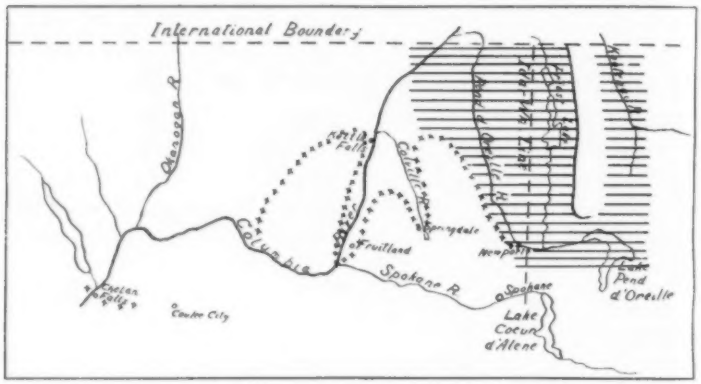

FIG. 1.—Sketch map of a portion of Idaho and Washington. Crosses indicate moraine according to Salisbury. Lined area shows extent of Pend d'Oreille–Priest River marginal lobe.

main ice-sheet. The upper limit of ice in these cirques was about 7,000 feet.[1] The Pend d'Oreille lobe therefore extended eastward as indicated by the lined area on the map.

The basins of Upper and Lower Priest lakes are deep and rock-floored, and suggest in all respects a valley scoured and enlarged by glaciation, and the lakes themselves can be attributed to no other cause than damming by morainal deposits. The country between the Upper and Lower lakes is low and swampy in most places, but deposits of coarse fragmental material are found; the outlet of the Lower Lake flows through a flat valley of sand

[1] All elevations given in this paper are based upon aneroid readings checked on U.S.G.S. elevation for Priest Lake 2,460 feet. As I was often away from this known elevation for several days, there is possibility of considerable error.

and gravel; and the streams flowing into the lake tumble over bowlder beds between banks of gravel and sand. It is noteworthy, however, that none of this detrital material—that separating the two lakes, that filling the main valley south of the lower lake, and that in the tributary valleys—shows any sign of morainal topography. It is arranged in terraces, somewhat modified by later erosion, but still forming distinctly flat-topped benches, and the bowlders and cobbles found in it indicate, by their partly rounded shape and the lack of striae, wear by water. The obvious conclusion is that upon the retreat of the ice this comparatively narrow valley was filled by a swollen, swiftly flowing stream that completely rearranged the morainal material. Mr. Calkins[1] has noted cases of similar reworking of glacial deposits east of here, but he found traces of true moraine. I know of no description of reworking of glacial deposits by stream action comparable in completeness to that at Priest Lake. An entirely similar condition was found at Sullivan Lake, a small mountain lake in Washington draining into the Pend d'Oreille River.

Having established the former existence of ice over the divide between the Pend d'Oreille and Priest Lake valleys, and its limitation on the east by the Priest Lake–Kootenai divide, we may consider the southern extent of this lobe. The Kootenai lobe probably extended to the southeastern lobe of Lake Pend d'Oreille,[2] but probably no farther, for there is no evidence of continental glaciation in the Cœur d'Alene Mountains immediately south of this lake. Glacial striae have been found at Cocollala, west of Lake Pend d'Oreille at an elevation of at least 200 feet above the lake.[3] It therefore seems probable that the ice of the Kootenai lobe, held back by the Cœur d'Alene Mountains on the south, spread westward down the Pend d'Oreille valley, and united with the Pend d'Oreille–Priest River lobe. The southern limit of the ice formed by the union of these two lobes was somewhere north of the outlet of Lake Cœur d'Alene if the conclusion that the gravel found there is an outwash plain is correct. It is possible, however, that this

[1] *U.S. Geol. Surv. Bull. 384.*

[2] Calkins, *ibid.*, p. 32.

[3] T. C. Chamberlin, *U.S. Geol. Surv., 7th Ann. Rept.*

material is reworked glacial material similar to that found at Priest Lake, and that the southern boundary of this lobe should be moved farther south. Mr. T. A. Bonser of Spokane, after a series of careful studies, believes that the ice extended at least as far as the city of Spokane, and occupied a part of the Spokane River valley. Until his results are published, however, we cannot definitely locate this southern boundary.

SUMMARY

The conclusions reached above are as follows:

1. The marginal lobe of the Cordilleran glacier occupying the Pend d'Oreille valley passed over the divide on the east and filled Priest Lake valley.

2. Salisbury's opinion is confirmed that if the Kootenai and Pend d'Oreille lobes were offshoots from a continuous sheet, their connection must have been north of the International Boundary.

3. The fronts of these two lobes united to form a continuous sheet of unknown extent to the south.

4. Fluviatile reworking of glacial deposits has been so extensive along the front of the Cordilleran ice-sheet that great caution must be used in marking the limits of glaciation. More careful studies will probably show that many localities in the Northwest which now show only the bedded bench gravels characteristic of water-work were at one time actually covered by the ice, and the line of the maximum extent of the Cordilleran glacier will have to be drawn farther south than it is at present.

AN EXPOSURE SHOWING POST-KANSAN GLACIATION NEAR IOWA CITY, IOWA

MORRIS M. LEIGHTON
University of Iowa

While collecting field data pertaining to the Pleistocene history of Iowa River, in Johnson County, Iowa, the writer recently examined a railway cut which furnishes some striking evidence, additional to that already presented by the late Professor Calvin, that a post-Kansan ice-sheet, much younger than the Kansan, invaded this part of the state of Iowa. It was thought, while this paper was being prepared, that no previous study of this interesting cut had been made, but Professor Shimek states that he examined the exposure some years ago.

The exposure is in a cut made in 1905 by the Cedar Rapids & Iowa City Interurban Railway. It is located ⅛ mile northwest of the upper Interurban bridge across Iowa River and about 15 miles by rail northwest of Iowa City. The railroad grade here runs through the south end of a divide projecting somewhat into Iowa River valley, the summit of the divide at the surface of the cut being about 30 feet above the valley flat. The physiographic setting is shown in Fig. 1. This is within the area mapped as Iowan drift by Calvin.[1]

The cut is about 250 yards long and attains a maximum depth of 20 feet. For about 120 yards, the east end is till, and for 100 yards at the west end the material is yellow fossiliferous loess. Between these are contorted folds and rolls of Buchanan gravel in peculiar relation to the Kansan till below and overlain by 2 to 8 feet of till. The arrangement of the materials is shown in Fig. 2.

The oldest material in the cut is Kansan till—blue at the bottom and grading up in places into a grayish to yellow color according to the degree of weathering. The blue is very clayey, contains small pebbles, many of which are greenstone, and breaks with polyhedral

[1] Samuel Calvin, *Iowa Geological Survey*, VII, opposite p. 92.

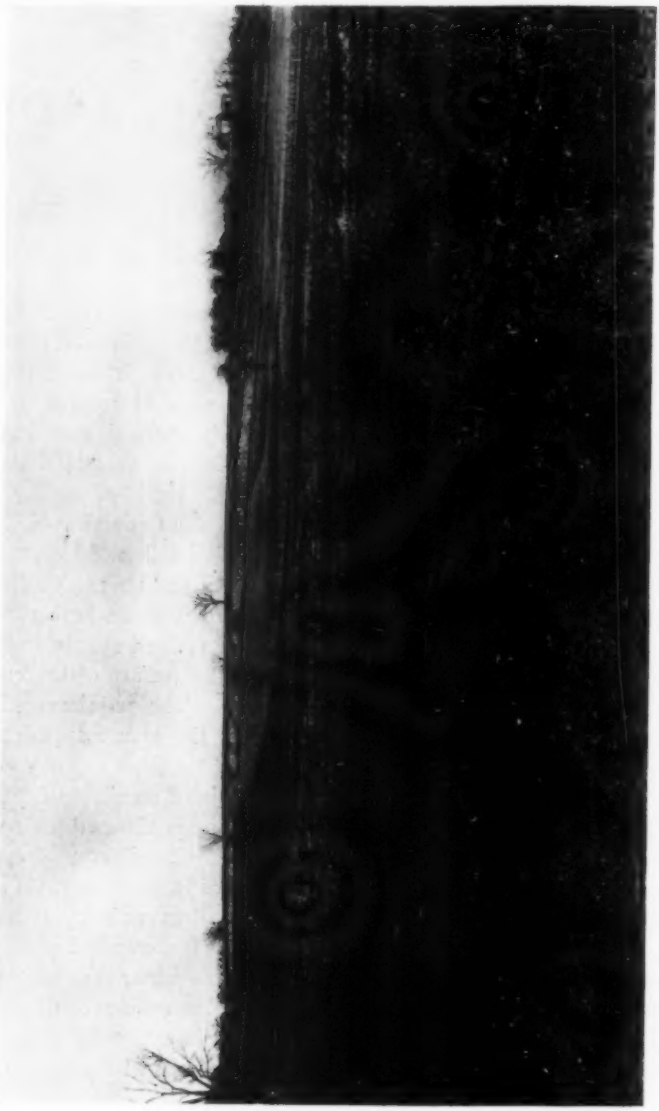

FIG. 1.—View looking north, showing the physiographic setting of the cut. The rolls can be faintly seen to the left of the east lone tree, on top of cut.

fracture. Joints are prevalent in the yellow clay and in the upper part of the blue, but instead of being vertical they dip toward the west, suggesting that they are the result of pressure from that direction. In that case they might be regarded as slight shear planes resulting from the same force that produced the distortion of the gravel above. Overlying this, in a peculiarly folded and contorted manner, is Buchanan gravel, the textural range of which is from fine flour to bowlders 1 foot in diameter. The gravel exhibits the usual oxidized, weathered, and decayed character. Ironstones are not uncommon and cementation by iron oxide is sufficiently prevalent to have preserved stratification lines at many points.

At the west end of this section (left end of Fig. 2), the gravel appears in a narrow band in the lower part and rises to the east at an angle of about 45 degrees, reaching a height of 16 feet. From this point the gravel follows a horizontal course eastward for about 75 feet and ends rather abruptly against till.

FIG. 2.—View of the north face of Interurban cut, 15 miles northwest of Iowa City, Iowa, showing the arrangement of Buchanan gravel on Kansan till and overlain by a later till. The numerical index is referred to in the text.

FIG. 1.—View looking north, showing the physiographic setting of the cut. The rolls can be faintly seen to the left of the east lone tree, on top of cut.

In this middle portion there is a peculiar series of contortions in the gravel. Reference to the photograph shows that (2) and (3) are two small, almost perfect, synclines of the closed type; (4) is a large, elongate body 27 feet long with an accumulation of small bowlders and gravel at the east end; (5) is a small elliptical roll having a nucleus of gravel with wrappings of till, all of which is surrounded by till; (6) marks a protruding compact body of gravel that has withstood slope-wash; (7) is a large downward loop 7 feet deep; and (8) and (9) appear as stringers projecting from the main body of the gravel into the till below.

At (1) and around the lower part of (7), the gravel, so altered that some cobbles can be picked to pieces by the fingers, rests against the blue unweathered till, and along the lower contact of (4) and around the lenticular body (5), the edge of a knife-blade can mark the separation of the oxidized gravel from the much less oxidized till. Till that is scarcely changed lies high in the arches between (7) and (8), and between (8) and (9). It is also striking that the gravel deep in the cut is as much weathered as that near the surface.

Overlying the gravel is a yellow, blue-streaked till, 2 to 4 feet thick across the summit, and attaining a thickness of at least 8 feet along the west monoclinal limb. On the western slope of this, beginning at the point (*x*) and lying in contact with the drift along a diagonal line (made clearer by dotting), lies yellow, fossiliferous loess which is not contorted but which shows deposition after the disturbance of the gravel. This body of loess is in the west end of the cut.

INTERPRETATION

To account for such folds, rolls, and contortions of Buchanan gravel into Kansan till in such a way as is revealed here, there can be but one possible interpretation. The sharp contact of the oxidized, altered, and rotten bowldery gravel upon unchanged till at points (1) and (7), and between (7) and (8), and between (8) and (9), and the sharp break below the elongate body (4) and around the lens (5) prove that the folding took place after the gravel was weathered. If the weathering had taken place since their disturbance, there should be at least a narrow gradation-zone between

the weathered and the unweathered portions. Such, however, does not occur. Besides the foregoing significant relations, the gravel is uniformly weathered at different depths, but the till is not.

The conclusion is therefore clear that an ice-sheet, capable of distorting and molding this hill of material, invaded this region after the Buchanan gravel and some of the Kansan till were much weathered.

In view of the above interpretation there are four important points embodied in this cut: (1) the Kansan drift and the Buchanan gravel record the invasion and retreat of the Kansan ice; (2) the weathering of the same represents a considerable time interval after the Kansan invasion; (3) the contacts record the close of that interval and the folds give identity to the presence of a later ice-sheet and its movement; (4) the yellow loess, at least in this exposure, was deposited subsequent to the advance and retreat of the later ice-sheet.

RECONNAISSANCE IN THE SOUTHERN WASATCH MOUNTAINS, UTAH[1]

G. F. LOUGHLIN
United States Geological Survey

CONTENTS

INTRODUCTION
Previous work
THE COTTONWOOD DISTRICT
Structure
Summary of Structural Evidence
Stratigraphy
THE AMERICAN FORK–ALPINE DISTRICT
THE PROVO DISTRICT
THE SANTAQUIN–MOUNT NEBO DISTRICT
Stratigraphy
Structure
Overthrusts
Block faults
SUMMARY

INTRODUCTION

The facts here presented were gathered during a reconnaissance of the ore deposits in central Utah for the United States Geological Survey during the summer of 1912. No time was available for thorough areal work, but certain of the results obtained in the southern half of the Wasatch Mountains seem to be of sufficient interest for presentation. The districts visited in the Wasatch country were the Big and Little Cottonwood districts, where the writer accompanied Mr. B. S. Butler of the Survey, the American Fork and Alpine districts, the Provo district, and the Santaquin–Mount Nebo district (see Fig. 1).

Previous work.—The only published accounts of previous areal work on the bedrock geology of the region are in the report of the

[1] Published by permission of the Director of the United States Geological Survey.

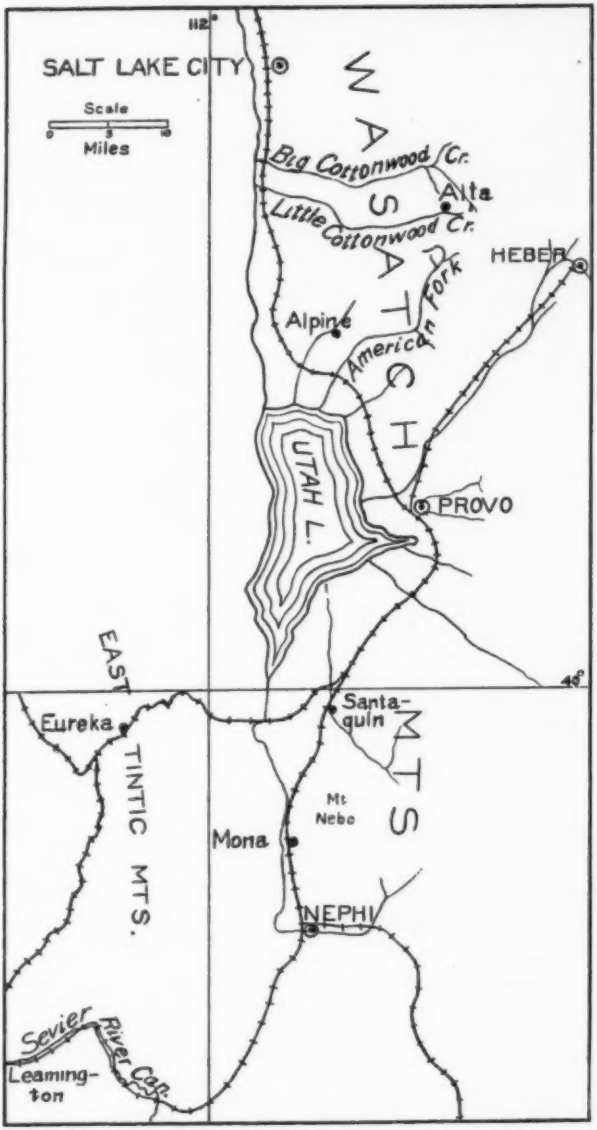

FIG. 1.—Sketch map showing positions of places mentioned in the text

Fortieth Parallel Survey, and that on the Park City mining district by Boutwell. Mr. F. S. Emmons, of the Fortieth Parallel Survey,[1] mapped the geology of the Wasatch Mountains from Provo Peaks northward, and his report gives brief mention of Mount Nebo 25 miles farther south—the highest and southernmost peak of the range. Mr. Emmons had only three weeks for his entire work in the Wasatch Mountains, and the amount of ground covered and the great quantity of data gathered by him in that time are indeed wonderful. It is only to be expected that his traverses did not lead him to all the places where the clues to stratigraphy and structure were exposed, and that in the absence of those clues certain evidence could not be finally interpreted. It is, however, a relatively easy matter for one aided by the Fortieth Parallel map to investigate certain special problems and to find evidence which modifies the interpretations originally given.

Boutwell has done considerable work in the country around the Cottonwood and American Fork districts,[2] and has thrown much light on the geology of both the igneous and sedimentary rocks; but his published detailed work on the latter deals chiefly with formations stratigraphically higher than those considered here, and the detailed descriptions of structure are confined to an area farther east than that visited by the writer. Boutwell, however, was the first to recognize overthrust faulting in the Wasatch Mountains.[3]

Blackwelder in 1910[4] made some interesting contributions to our knowledge of the northern Wasatch Mountains, eliminating the "Ogden (Devonian)" quartzite of the Fortieth Parallel Survey and discovering several great overthrust faults. He also examined the Big Cottonwood Canyon section and found an unconformity in the great quartzite series, correlating the overlying 1,500 ft. of the quartzite as Cambrian and the underlying 10,500 ft. as Algonkian.

[1] *U.S. Geol. Explor. of the Fortieth Parallel*, II (1877), 342–66.

[2] J. M. Boutwell, "Geology and Ore Deposits of the Park City District, Utah," *Prof. Paper 77, U.S. Geol. Survey*, 1912.

[3] J. M. Boutwell, "Stratigraphy and Structure of the Park City Mining District, Utah," *Jour. Geol.*, XV (1907), 456–57.

[4] E. Blackwelder, "New Light on the Geology of the Wasatch Mountains, Utah," *Bull. Geol. Soc. of America*, XXI (1910), 517–42.

The results here presented are essentially a sequel to Blackwelder's work. To avoid repetition the evidence will be considered by districts rather than according to stratigraphy and structure.

FIG. 2.—Geologic map showing the intrusive granite (probably post-Jurassic), Cambrian quartzite (-Cq), and the great Cambrian to Mississippian limestone belt (*lst*) in the Cottonwood and American Fork–Alpine districts. The width of the narrow "lower" limestone belt at Alta is somewhat exaggerated. *W* = Weber quartzite; *Pre-C* = pre-Cambrian. Topographic base taken from the Salt Lake sheet, United States Geological Survey.

THE COTTONWOOD DISTRICT[1]

Structure.—The arrangement of formations in this district is, as shown in Fig. 2, and more completely on the Fortieth Parallel

[1] The term Cottonwood district is here used to include the area around the upper parts of Big and Little Cottonwood canyons.

Survey map, a rudely elliptical mass of granite surrounded on three sides by a concentric succession of sedimentary rocks. The granite, originally called Archean, was proved by Mr. Emmons in 1903[1] to be intrusive and probably of post-Jurassic age and his conclusions have been sustained by Boutwell.[2] The sedimentary rocks were originally correlated as follows:

Permo-Carboniferous and later
Upper Coal Measures limestone
Weber quartzite, Carboniferous
Wasatch limestone (intercalated series at the top), mostly lower Coal Measures
Ogden quartzite, Devonian
Ute limestone, Silurian
Quartzite (clay slates at the top), Cambrian

The present writer, however, during his first day in the district found fossils in the lower limestone belt (called the "Ute" in the above table) of Madison (Lower Mississippian) age. These fossils were collected on the spur between the two cirques just over the divide northwest of Alta, and were determined by Dr. Girty of the Survey as follows:

Syringopora sp.	Syringothyris (?) sp.
Zaphrentis sp.	Composita sp.
Amplexus sp.	Cleiothyridina crassicardinalis
Spirifer centronatus	Euomphalus sp.

These fossils are in part duplicated by fossils found in the great upper limestone belt (the "Wasatch" limestone of the Fortieth Parallel Survey), the greater part of which appears to be of Madison age. The fossils collected from this belt were determined by Dr. Girty as follows:

Syringopora sp.
Zaphrentis sp.
Spirifer centronatus

The presence of two belts of Mississippian limestone separated by a quartzite belt at once suggested the presence of an overthrust fault, which is proved by the following evidence. The "lower" limestone extends northward for about half-way down the Mill D

[1] S. F. Emmons, *Amer. Jour. Science*, 4th series, XVI (1903), 139–47.

[2] J. M. Boutwell, *op. cit.*, p. 156.

South Fork of Big Cottonwood Creek, where it appears to be overridden by the "upper" quartzite (the "Ogden" in the above table), which here rests directly, though discordantly, upon the lower (Cambrian) quartzite. The "lower" limestone is absent to the northwest in Big Cottonwood Canyon. Southward from Alta the "lower" limestone extends in a synclinal attitude between the two quartzite belts as far as the head of American Fork Canyon, where it passes through a complication of faults and local contortions and finally merges into the great "upper" limestone belt (see Fig. 2). Middle Cambrian fossils found by Mr. Butler in shale members of the "upper" quartzite both north and south of Alta confirm the structural evidence of an overthrust. These fossils were determined by L. D. Burling as follows:

Zacanthoides cf. spinosus
Obolus (westonia) ella
Micromitra (Iphidella) pannula

The overthrust structure, however, is complicated by two or more later fault systems. The older and more conspicuous of these was evidently developed by the stresses induced by the granite intrusion. The intrusion effected a domal uplift of the Paleozoic and Mesozoic rocks, and the force was great enough to rupture the dome in places, forcing the more central portions upward and outward against the outer portions. The strongest of these faults is best exposed on the north side of Little Cottonwood Canyon about half a mile west of Alta (Figs. 2 and 3), where the "lower" quartzite and shale, badly contorted, abut against the "lower" limestone along a steep westward-dipping fault plane. A second similar, but smaller, westward-dipping reverse fault is exposed about three-fourths of a mile east of the first, along the divide between Little Cottonwood Canyon and Mill D South Fork. The effects of these later reverse faults in obscuring the earlier overthrust are shown in Fig. 3. Both of the later reverse faults die out northward along the strike rather rapidly; southward the same, or similar, parallel faults are exposed near the head of American Fork Canyon, and the western one (nearer the granite) appears to continue in a southwestward direction as far as the Silver Lake cirque, beyond which the quartzite belt is cut off by the intrusive granite.

Besides these later reverse faults there are still later normal faults, some of which parallel the reverse faults and serve further to complicate the structure. Only one is indicated in Fig. 3. Some of the normal faults are mineralized, but as the writer's four-day visit to the district was almost wholly confined to surface work, he cannot consider them further than to state that the few veins seen by him, some of which lie along well-defined faults, appear to bear a radiating and concentric relation to the granite mass. Mapping of all the veins in the district may disprove this

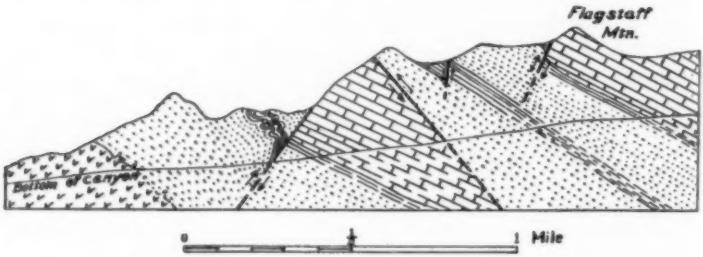

FIG. 3.—N.E.–S.W. section on the northwest side of Little Cottonwood Canyon, northwest of Alta, showing the effect of faulting upon the distribution of the Cambrian quartzite and the Cambrian to Mississippian limestones. The east-dipping overthrust is the oldest, the west-dipping reverse faults are later and directly related to the intrusive granite shown at the left. The normal fault in the central part is only one of several which were not mapped in detail.

hasty statement. Whether or not there are important faults still later than the period of mineralization the writer cannot say.

It may, however, be well to emphasize the relations of the two limestone belts to the distribution of ore bodies. Both belts contain producing mines, and during the writer's visit, in July, 1912, it is said that certain companies operating in the eastern or "upper" limestone belt were planning to sink to the "lower" belt in the hope of finding new ore bodies. The presence of the overthrust faults, as shown in Fig. 3, gives such a plan little hope of success. It cannot yet be said just how far the overridden belt extends eastward beneath the "upper" quartzite, but it is highly probable that it pinches out within a rather short distance.

Summary of structural evidence.—The "lower" limestone, formerly called the "Ute (Silurian)" by the Fortieth Parallel Survey, is proved to be a part of the Mississippian and older limestones overridden by a slab of the Cambrian quartzite which was formerly called "Ogden" and referred to the Devonian. This overthrust of eastward dip, was broken by at least two parallel reverse faults of steep westward dip which were formed during the domal uplift which accompanied the granite intrusion. Still later normal faults further complicate the structure.

Stratigraphy.—The stratigraphy east of the reversed faults, or from the "upper" quartzite belt upward, consists of a thin belt of Cambrian shale, which grades upward into the great limestone belt. The lowest limestone beds may be Cambrian also, but the greater part of the limestone contains Mississippian fossils. No careful measurements of thickness were made, but a rough estimate shows that there cannot be much more than 2,000 ft., and maybe much less, of pre-Mississippian limestone and shale. This is in marked contrast to the stratigraphy in the northern Wasatch Mountains and in the Uinta Mountains to the east. In the former, Cambrian limestones and shale above the quartzite aggregate 5,415 ft.[1] and are themselves separated from the Mississippian by 1,000 to 1,200 ft. of Ordovician and 1,000 to 1,500 ft. of Silurian and Devonian limestones.[2] In the latter, on the contrary, the entire great limestone belt is only 700 to 1,000 ft. thick, and Weeks[3] correlates its lowest beds with the Mississippian. The upper part he assigns to the Pennsylvanian. The Silurian and Devonian have been shown by Weeks and Ferrier[4] to thin southward and eastward, and they may not be represented so far southward as the Cottonwood district; but the exact stratigraphic relations cannot be accurately determined by mere reconnaissance work.

[1] C. D. Walcott, "Cambrian Brachiopoda," *Mon. U.S. Geol. Survey*, No. 51, Vol. I (1912), 148–52.

[2] E. Blackwelder, *op. cit.*, pp. 527–28.

[3] F. B. Weeks, "Stratigraphy and Structure of the Uinta Range," *Bull. Geol. Soc. America*, XVIII (1907), 432–41.

[4] F. B. Weeks and W. F. Ferrier, "Phosphate Deposits in Western United States," *Bull. U.S. Geol. Survey*, No. 315 (1906), p. 451; F. B. Weeks, "Stratigraphy and Structure of the Uinta Range," *Bull. Geol. Soc. America*, XVIII (1907) (correlation table). Silurian and Devonian are not represented in the Uinta Range.

The Mississippian limestone is followed upward by a considerable thickness of limestone, shale, and sandstone, which is succeeded by the Weber (Pennsylvanian) quartzite, and the Weber in turn is overlain by the Park City (Permian?) and Mesozoic formations. No measurements of the thickness of any of these formations were made.

THE AMERICAN FORK–ALPINE DISTRICT

The strata along upper American Fork Canyon south of Mary Ellen Gulch are almost entirely of the great limestone belt, striking about parallel to the neighboring granite contact and dipping away from it (see Fig. 2). The dip undulates gently, and at one place erosion has evidently exposed the top of the quartzite, presumably along a low anticlinal flexure; but the one quartzite outcrop found is completely isolated in an area of glacial drift, and its structural relations can only be inferred. Near the great bend in American Fork Canyon the uniformity of strike and dip is interrupted by an anticlinal or domal structure in which the Cambrian quartzite is exposed along the lower canyon walls. The southern part of the dome is cut off by an E.-W. fault, with relative upward movement on the north side. Two miles below the bend, the quartzite is again exposed along the lower canyon walls in a second domal uplift. About midway between this second dome and the town of Alpine to the northwest, the quartzite is again exposed in a third domal uplift, which like the first is broken by a fault. The fault is exposed along the range front and is clearly of the reversed type, with steep northward dip (toward the granite). As these faulted dome structures are essentially small duplicates of the great faulted dome around the intrusive granite, they may indicate the presence of unexposed intrusive granite bosses south of the exposed granite area. This suggestion is strengthened by the fact that the southern granite contact pitches southward beneath the contact-metamorphosed limestones. The southerly pitch is well shown at the Silver Lake cirque about 4 miles east of Lone Peak, where limestone forms the west wall, and quartzite and limestone the east wall, but where granite forms the north wall and the floor.

The quartzite exposures in American Fork Canyon were regarded as Devonian by the Fortieth Parallel Survey, as their

exposed thickness was not too great and no other quartzite occurred above them; but since they have the same stratigraphic position as do the fossiliferous Cambrian "upper" quartzite and shale in the Cottonwood district, there can be no reasonable doubt of their Cambrian age. There are several good exposures of shale just above the quartzite areas, and it is in these that fossils are to be expected. South of American Fork Canyon the strata pitch southward, and along the west foothills of Timpanogos Peak, east of Pleasant Grove, the Mississippian limestone reaches nearly or quite down to the level of the Lake Bonneville shore line. Timpanogos Peak was not ascended.

THE PROVO DISTRICT

As only one short day was spent at Provo, remarks will be limited to the two quartzite occurrences along the lower front of Provo Peaks. They are both exposed along anticlines which are in line with each other, but oppositely unsymmetrical. The northern exposure forms a low arch for about 3 miles along the range front, and is nearly bisected by the mouth of Rock Creek Canyon, northeast of Provo. Near the mouth of the Canyon the quartzite is flanked by a still lower body of dark argillaceous limestone, which at the mouth of the canyon is faulted against it. No fossils were found in the limestone, and its physical characters were of too indefinite and general a character to permit a definite correlation with any members of the great limestone belt above the quartzite, though such a correlation is possible. It is also possible that this lower limestone is intercalated within the quartzite. Pebbles of impure limestone were found in a dark conglomerate bed in the quartzite at the canyon mouth, but represented, on weathered surface, a light-gray, finely banded type and not the dark type in question. The pebbles, however, indicate the presence of limestone in Cambrian or earlier time, and an unconformity possibly within the Cambrian.

The quartzite and its overlying shale have a gentle eastward dip for a short distance, but just above the mouth of the canyon they steepen abruptly and are slightly overturned, dipping 80° westward. The great limestone belt lies above the overturned portion

with a very gentle and uniform easterly dip, as if it had slid bodily westward over the quartzite and shale; but, as the writer entered the canyon at sunset he had no opportunity to get more than a hasty glance at the structure. Mr. Emmons remarked that the structure, as seen from the canyon bottom, appeared to be a strong unconformity, but that examination the whole length of the canyon proved the structure to be an S-shaped fold with only its upper half exposed.[1] The limestone cliffs show the same succession of limestones as that which overlies the Cambrian quartzite and shale in the Cottonwood district, and the quartzite exposures at Provo are therefore to be assigned to the Cambrian, and not to the Devonian as was done by the Fortieth Parallel Survey.

The southern quartzite occurrence, southeast of Provo, also forms an arch along the range front, cut by Slate Creek Canyon. In this case, however, the western limb is very steep. The quartzite is exposed approximately along the axis and is flanked by overlying limestone dipping steeply westward. The east limb, which can be studied along the walls of Slate Creek Canyon, dips very gently and is overlain by about 200 ft. of shale and the regular succession of limestone beds. The conglomerate bed with light-gray limestone and other pebbles is exposed in the canyon near its mouth, and beneath it in the creek bed is a doubtful outcrop of dark bluish-black limestone similar to that flanking northern quartzite exposure. The evidence in the two cases, though not absolutely convincing, is thus consistent and points to the existence of a local limestone horizon below, or within, the quartzite, and also to the existence of an unconformity below the exposed part of the Provo section, presumably in Lower Cambrian time.[2] Limestone beds of Middle Cambrian, and one small bed of Lower Cambrian or even earlier age, were found by the writer intercalated in the great quartzite series of the Simpson Mountains north of the

[1] *Op. cit.*, pp. 345–46.

[2] According to Walcott ("Cambrian Sections of the Cordilleran Area," *Smithsonian Inst. Misc. Coll.*, 1908), the first 100 ft. of shale above the basal quartzite in Big Cottonwood Canyon are Lower Cambrian and next 150 ft. are Middle Cambrian. The quartzite at Provo, 25 to 30 miles farther south, may therefore also be regarded as approximately at the top of the Lower Cambrian.

Sevier Desert in June, 1912, but none farther east are known save this obscure Provo occurrence.

THE SANTAQUIN–MOUNT NEBO DISTRICT

Santaquin is about 18 miles S.S.W. of Provo. The Wasatch Range from here southward to Mount Nebo is interesting both from a stratigraphic and structural standpoint.

Stratigraphy.—The oldest formation in the district is a band of pre-Cambrian gneissoid granite with large included bodies of schists, exposed for 2 miles or more along the lower range from east of Santaquin. It is quite different in texture from the granite of the Cottonwood district, and is overlain unconformably by Cambrian quartzite, the basal beds of which contain quartz and coarse red feldspar fragments derived from the pegmatitic facies of the granite. The quartzite formation dips 28° east and does not appear to be over 800 ft. thick. It varies in texture from conglomerate to shale, and in color from white to dark red and brown. In its upper half are a few dark-green beds with a high iron content. The quartzite passes upward into shale in which Cambrian trilobites have been found. The shale is followed by alternating beds of argillaceous limestone and shale, and finally by continuous limestone which at the top of the ridge includes a part of the upper Mississippian "intercalated series."

The Mississippian limestone is abundantly fossiliferous, and the lowest Mississippian fossils were found at a horizon about 2,400 ft. above the top of the quartzite. No fossils in the intervening limestones were found, but the lithologic succession as a whole is very similar to that of the lower half of the limestones of the Tintic district, about 20 miles to the southwest, which total 3,500 ft. in thickness and are chiefly or wholly Cambrian. No unconformity was detected, but so far as comparisons can be made the Mississippian limestones in the Santaquin, as well as in the Cottonwood district, lie on a much thinner series of limestone than is the case in the Tintic district to the west or in the northern Wasatch Mountains.

The upper Mississippian "intercalated series" is overlain unconformably on the east flank of the ridge by a coarse reddish

conglomerate, part of which consists of quartzite, chert, and limestone pebbles, and part of calcareous beds full of peculiar concretionary growths. Some of these concretions resemble shells in form, and one undoubted gastropod was found, which Dr. T. W. Stanton of the Survey says may be a fresh-water Eocene species. The unconformity implies the removal by erosion of the Weber quartzite, the Park City formation, and the Mesozoic formations which overlie these formations in the Park City district. Overlying the Eocene conglomerate is a coarse andesitic (or latitic) breccia. Its outcrops are weathered and largely reduced to aggregates of loose cobbles some nearly a foot in diameter, and the nature of its contact with the underlying conglomerate, whether conformable or unconformable, could not be determined.[1] Intrusive volcanic rocks are limited to a few dikes, also of andesitic or latitic character.

In the low hills south and southwest of Santaquin, a veneer of Eocene conglomerate with remnants of the volcanic breccia overlies limestones of pre-Mississippian (probably Cambrian) age, and 35 miles farther southwest, in the Sevier River Canyon, the same Tertiary sequence of rocks rests unconformably upon the Cambrian quartzite. Nearly the whole Paleozoic, as well as the Mesozoic, section in central Utah is thus beveled off by this unconformity, as is the case in the Uinta Mountains in northeastern Utah.[2]

The last two Eocene occurrences mentioned are somewhat farther west and north than any previously mapped, and it is believed that they are not far from the original limits of the Eocene in this region; for in Long Ridge and the East Tintic Mountains, about 12 miles southwest of Santaquin, the same type of andesitic breccia rests either directly upon Paleozoic rocks, or is separated from them by an intervening body of effusive rhyolite, and no sedimentary rocks later than Paleozoic have been found.

Structure.—The principal structural features in the Santaquin–Mount Nebo district are faults, including doubtful overthrusts of

[1] C. K. Leith and E. C. Harder. (*Bull. U.S. Geol. Survey*, No. 338 (1908), pp. 18 and 21) have proved an unconformity between Cretaceous and Eocene beds in the Iron Springs district of southern Utah and a later unconformity between the Eocene beds and Miocene lavas.

[2] F. C. Weeks, *op. cit.*, p. 442.

N.-S. trend and a series of N.-S. and E.-W. block faults of the Basin Range type (see Fig. 4). The former are so poorly exposed, their courses so nearly parallel to the N.-S. system of the block faults, and, in some places, the rocks along them so free from severe crumpling or crushing, that the writer is not fully convinced of their overthrust character.

Overthrusts: East of Santaquin the northern part of the pre-Cambrian granite appears to overlie quartzite, but the contact is concealed by float. A little farther northward, however, the granite pinches out and the main body of Cambrian quartzite overlies a dark brecciated limestone, which passes downward into shale and quartzite. This lower quartzite exposure, in turn, overlies fossiliferous Mississippian limestone, which is very free from any of the crumpling or brecciation which is likely to accompany overthrusting. The Mississippian limestone is underlain conformably by fossiliferous Cambrian shale and a third quartzite exposure.

The pre-Cambrian granite southward disappears beneath a high alluvial fan which is now trenched by Santaquin Creek; but the main Cambrian quartzite body continues, and at its southernmost exposure rests again upon fossiliferous Mississippian limestone, which, as in the other instance, is surprisingly free from contortions and crushing. So far as the positions of the rocks are concerned, reverse or overthrust faulting seems the only interpretation; but the absence of disturbance in the overridden limestone is not easily explained.

At the mouth of Green Canyon, 8 miles south of Santaquin, an extremely brecciated and, so far as seen, non-fossiliferous limestone dips eastward beneath Cambrian quartzite, and here is the most convincing evidence of an overthrust, although time did not permit a thorough study of the immediate contact. A tunnel of the Excelsior Mining Company has been driven through the limestone into the quartzite, but the entrance to it was locked at the time of the writer's visit. No fossils were found in the underlying limestone, but the presence on the dump of fragments of a highly carbonaceous and finely pyritic bed, similar to two found elsewhere in the Mississippian of the southern Wasatch Mountains and of the Tintic district, gives a clue to the age of the limestone, and

accords with the structural relations in showing the fault to be an overthrust.

Block faults: A striking difference between the faults just described and the undoubted normal, or block, faults of the district

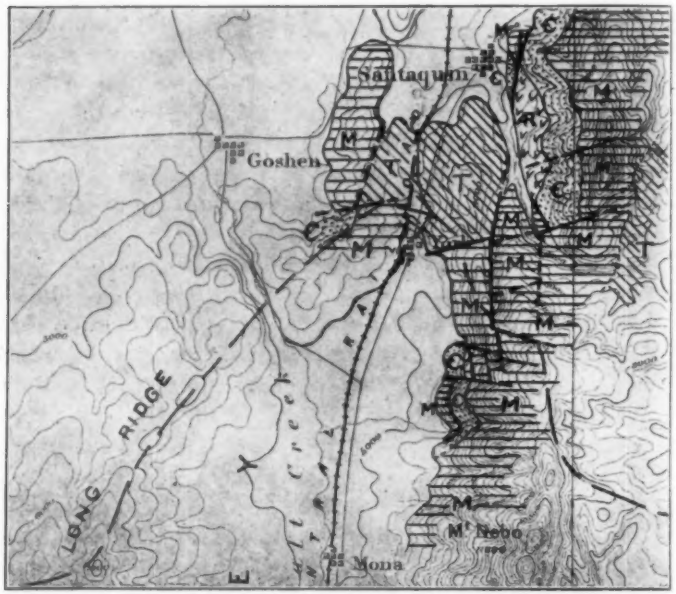

FIG. 4.—Geologic map of the Santaquin–Mount Nebo district showing overthrusts and block faults. $\mathcal{R}$ = pre-Cambrian granite, ϵ = Cambrian quartzite; M = Mississippian and earlier limestones; T = Tertiary conglomerate and volcanics. Topographic base from the Manti sheet, United States Geological Survey.

is that the latter are marked by longitudinal and, to a less degree, by transverse valleys, whereas those interpreted as overthrusts appear unrelated to topography. From Santaquin southward nearly to Green Canyon (see Fig. 4) the western side of the range is composed of parallel ridges separated by remarkably straight N.-S. canyons. The strata on opposite sides of these canyons are quite discordant. For example, just north of Wash Canyon (6 miles south of Santaquin), the upper Mississippian "intercalated series"

with gentle easterly dip forms the low western ridge, and the pre-Mississippian limestones lie directly opposite on the west face of the main ridge. The "intercalated series" forms the crest of the main ridge, about 2,000 ft. above the western ridge. To the south across Wash Canyon, which follows a nearly E.-W. fault, the "intercalated series" is followed by Cambrian quartzite and limestones, and farther south a second E.-W. fault cuts off the Green Canyon overthrust. To the north, the "intercalated series" of the western ridge abruptly gives way, at another E.-W. fault, to the Eocene sediments and later volcanic breccia, which cover the low hills west of Santaquin Canyon, whereas the face of the main ridge east of the canyon is made up of the pre-Cambrian complex and lower Paleozoic strata, and the Tertiary beds are found only along its eastern base. The most obvious E.-W. (N. 70° E.) fault in the district is on the west side of the main ridge in a ravine just north of Santaquin Canyon, where the entire Cambrian quartzite and the overridden Mississippian limestone beneath it are cut off and followed on the south side by the lower (probably Cambrian) limestone beds.

It is of some interest to add that faulting later than the Tertiary volcanic flows was found by the writer last year in the East Tintic district and that this accords with the more convincing evidence in the Santaquin–Mount Nebo district, where the presence of faulted Eocene conglomerate and late or post-Eocene volcanic breccia places the time of the faulting and range uplifts not earlier than Miocene, thus confirming existing conclusions regarding the age of the basin ranges.

SUMMARY

In the Cottonwood district the "Ute" limestone and "Ogden" quartzite recognized by the Fortieth Parallel Survey are shown to be respectively parts of the Mississippian (and older) limestones and Cambrian quartzite.

The latter has overridden the former along an overthrust fault of easterly dip.

This overthrust is broken by at least two later reverse faults of westerly dip which were formed during the domal uplift induced by the granite intrusion.

Still later normal faults further complicate the structure.

The Mississippian limestone does not appear to be over 2,000 ft., and may be much less, above the Cambrian quartzite. The thickness of pre-Mississippian limestones is much less than in the northern Wasatch country, and greater than in the Uinta Mountains.

Cambrian quartzite, formerly called "Ogden (Devonian)," is exposed in three domal uplifts in the American Fork–Alpine district. Two of the domes are faulted, and the similarity of the structure to that in the Cottonwood district suggests that outlying bosses of the granite may underlie the domes.

Cambrian quartzite in the Provo district is exposed along two anticlines in line with each other, but oppositely unsymmetrical. A conglomerate bed in the quartzite contains impure limestone pebbles, indicating the existence of limestone of Cambrian or earlier age and an unconformity, presumably in the Lower Cambrian. Obscure exposures of dark limestone may represent a local bed intercalated in the quartzite, but the evidence at hand is not convincing.

In the Santaquin–Mount Nebo district the lowest exposed rocks are pre-Cambrian granite and schist, overlain unconformably by about 800 ft. of Cambrian quartzite, which is followed by 2,500 ft. of shale and limestone, in part or wholly Cambrian, and by Mississippian limestone. The upper Mississippian "intercalated series" east of Santaquin is overlain unconformably by Eocene conglomerate and volcanic breccia. To the west and southwest, the Eocene conglomerate rests upon pre-Mississippian limestone and Cambrian quartzite, proving the unconformity to have beveled off nearly the entire Paleozoic, as well as the Mesozoic, section. These latter occurrences mark approximately the western limit of Eocene sedimentation in central Utah.

Both overthrust and block faults are present in the Santaquin–Mount Nebo district. The former are for the most part obscure, but in each case are marked by Cambrian quartzite resting upon Mississippian limestone. The block faults are marked by N.-S. and E.-W. canyons, and are shown to be of post-Eocene age.

NEW SPECIES FROM THE SANTA LUCIA MOUNTAINS, CALIFORNIA, WITH A DISCUSSION OF THE JURASSIC AGE OF THE SLATES AT SLATE'S SPRINGS

CHARLES H. DAVIS

It is proposed in this paper to give very briefly the results of studies of the invertebrate fauna of the Franciscan slates at Slate's Springs, showing, first, that the fauna is older than the lower Knoxville, which itself is now being placed by many geologists in the Upper Jurassic (the slates, indeed, are much more faulted and metamorphosed than the sandstones of the Knoxville and dip under the Knoxville); secondly, that the fauna is not pre-Jurassic; and thirdly, that the molluscan fossils found at Slate's Springs, and named in this paper, are closely related to the described forms from the Middle Jurassic of Cook Inlet and the Alaska Peninsula, and from the Jurassic of Queen Charlotte Islands.

The locality under discussion is a narrow strip of seacoast extending from Point Sur southward to Slate's Springs, a distance of eighteen miles. About four miles north of the springs, collections of molluscan fossils and a few fragments of plants were made by Dr. H. W. Fairbanks[1] and Mr. F. M. Anderson in 1894. These collections are now in part in the Leland Stanford Junior University paleontological collection, and in part in the collection of the University of California.

It has been the work of the writer to describe and name what are judged to be new species from the above-mentioned collections, and to make note of those specimens which are too poor to serve for the identification of species. The *Sequoia fairbanksi*, described by Fontaine, is the only named fossil from this locality. The pecten from the San Luis formation of Fairbanks, and collected by him from a locality six miles north of Port Harford, San Luis Obispo County, is also described in this paper.

[1] "Geology of the Southern Coast Ranges," *Jour. Geol.*, VI (1898), 551–76.

The tellina here described was found among fossils characteristic of the Lower Temblor on the northern headwaters of San Antonio Creek, Monterey County.

SPECIES LISTED AND NAMED FROM SLATE'S SPRINGS

Pleuromya (?) undulata (n. sp.), L.S.J.U. FIG. 4.
Grammatodon inornatus Meek and Hayden.
Yoldia arata Whiteaves.
Nucula (acila) sp.
Inoceramus lucianus (n. sp.), L.S.J.U. FIG. 2.
Alaria fairbanksi (n. sp.), U. of C. FIG. 1.
Sequoia fairbanksi Fontaine.

FROM NEAR PORT HARFORD, SAN LUIS OBISPO COUNTY, CALIFORNIA

Pecten (Camptonectes) harfordus (n. sp.), L.S.J.U. FIGS. 3, 5, 6.

FROM UPPER SAN ANTONIO CREEK, MONTEREY COUNTY, CALIFORNIA

Tellina tenuistriata (n. sp.), L.S.J.U. FIG. 7.

DESCRIPTION OF SPECIES

Pleuromya (?) undulata (n. sp.). FIG. 4.

The specimens in the L.S.J.U. collection closely resemble *Pleuromya (?) carlottensis* Whiteaves,[1] but are somewhat larger. The specimen from Slate's Springs is strongly marked by broad concentric grooves, a characteristic not marked in the *P. concentrica* Whitfield and Hovey.[2] The right valve is distinctly convex in front and along the sides, becoming slightly concave at the posterior margin; outline ovate, short and rounded in front, produced and blunt posteriorly. The beaks are situated a distance of about one-fourth from the anterior end, apices wide but not acute. The hinge-line behind the umbones is almost straight, curving slightly upward at the posterior end; ventral margin broadly rounded. The surface is strongly and concentrically ribbed—the ribs separated by deep concave grooves.

Dimensions: Length, 3½ inches; height, 2 inches; thickness of closed valves, 1½ inches.

(?) *Grammatodon inornatus* Meek and Hayden.

One nearly perfect specimen of a left valve, several specimens showing middle and anterior end. The characters and dimensions agree with the description of *G. inornatus* by Whitfield.[3]

[1] Geol. Surv. Canada, *Mesozoic Fossils*, I, Pt. I (1896).

[2] *Am. Mus. Nat. Hist.*, XXII (1906), 389–402.

[3] *Geol. Black Hills of Dakota* (1880), p. 359, Pl. 5, Figs. 16–18.

Dimensions: Length, 18 mm.; height, 10 mm.; thickness of closed valves, 5 mm.

Cf. *Yoldia arata* Whiteaves, Geol. Surv. Canada, *Mesozoic Fossils*, I, Pt. III, p. 233, Pl. XXXI, FIGS. 4 and 4*a*.

A single specimen, rather poor, but showing clearly the attenuate posterior end, elongation, strong concentric striations, and shallow concave slope of hinge from beaks to posterior end.

Dimensions: Length, 14 mm.; height, 6½ mm.; thickness of closed valves, about 4 mm.

Nucula (*acila*) sp.

Shell small, nearly equilateral; subovate,

FIG. 1.—*Alaria fairbanksi*, natural size.

FIG. 2.—*Inoceramus lucianus*, one-half natural size.

moderately convex but depressed toward basal margin. Ribs divaricate from imaginary line running from beak to basal margin slightly anteriorly. Extreme length of shell from 7 to 15 mm. The wide range and common characteristics of the *Nucula* (*acila*) give it little determinative value.

Inoceramus lucianus (n. sp.), FIG. 2.

Several imperfect and broken specimens are in the L.S.J.U. collection. The one giving the best conception of the type is a cast of a left valve. The form is ovate or subquadrate, cardinal margin straight, basal margin semicircular. The beaks are rather low but pointed. The ribs on the type specimen are flattened by the pressure to which the rock has been subjected, but

other specimens show broad unequal concentric folds, often deep, as in the case of *I. elliotii* Gabb.

Height, $4\frac{1}{2}$ inches, is slightly greater than the length, $3\frac{3}{4}$ inches. This inoceramus is not of the catillus type.

This species resembles *I. vancouverensis* in general size and outline, and in the direction of the hinge-line.

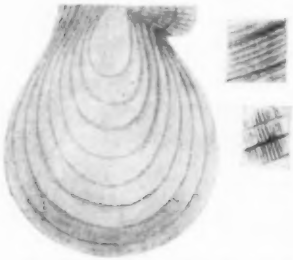

FIG. 3.—*Pecten (Camptonectes) harfordus*, twice natural size. (The details are four and eight times natural size.)

Alaria fairbanksi (n. sp.), FIG. 1.

A single imperfect specimen is in the paleontological collection of the University of California, and was collected by Dr. H. W. Fairbanks. The expanded outer lip and turreted form suggest the *Alaria*, a species of which occurs in the Vancouver Coal Measures.[1]

Dimensions: Height 55 mm.; thickness, about 20 mm.; extension of lip beyond shell proper, 15 (?) mm.

Sequoia fairbanksi Fontaine, *Mon. 48, U.S.G.S.* (1905), p. 78, Pl. XLV, FIGS. 9–11.

"From the Jurasso-Cretaceous of Slate's Springs, California. Collected in the rocks underlying the Knoxville group of the Lower Cretaceous. This

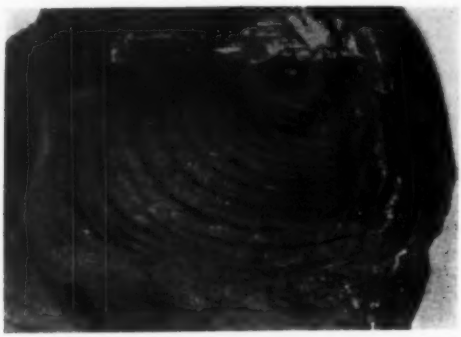

FIG. 4.—*Pleuromya undulata*, one-half natural size

plant is not unlike those from the Jurassic called by Heer, Elatides" (*op. cit.*).

Pecten (Camptonectes) harfordus (n. sp.), FIGS. 3, 5, 6.

[1] Cf. *Anchura stenoptera* Goldfuss (sp.) Whiteaves, Geol. Surv. Canada, *Mesozoic Fossils*, I, Pt. II, p. 123, Pl. 15.

A small thin pecten; form ovate, nearly smooth, and marked with fine almost microscopic groovings which radiate from the umbo and are deflected laterally from a median line on each valve. The shell is marked also by fine concentric lines, every fifth or sixth of which is more distinct. The anterior auricle is large; the anterior edge forms a right angle with the cardinal margin,

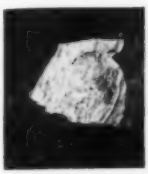

FIG. 5

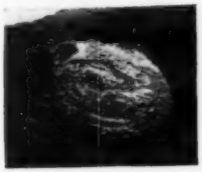

FIG. 6

FIGS. 5 AND 6.—*P. (Camp.) harfordus*, natural size

and rounds sharply into the deep byssal sinus. The left auricle is small and obliquely trunkated. The beaks are sharp and stop at the hinge-line.

This pecten is compared by Stanton[1] to *Pecten pedroanus*, but the latter differs from these specimens in having stronger radial markings especially on

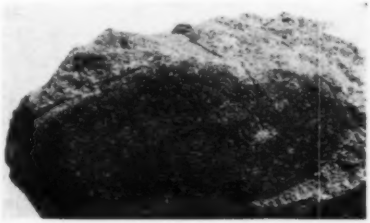

FIG. 7.—*Tellina tenuistriata*, natural size

the auricles, and in general outline. It is like *P. bellistriatus* in its sculpture but is smaller; it has finer markings than *P. extenuatus* Meek.

Tellina tenuistriata (n. sp.), FIG. 7.

The specimens collected by the writer are from the Lower Temblor on the northern San Antonio headwaters, Monterey County, Cal. They are characterized by the fine concentric lines on both valves, and low beaks. The valves are rounded in front but are oblique and gaping behind; more or less rostrate.

Dimensions: Length, 2 inches; height, $\frac{7}{8}$ inch; thickness, $\frac{1}{2}$ inch.

[1] U.S.G.S., *San Luis Folio*.

CONCLUSIONS

First: The slate formation at Slate's Springs dips unconformably under the basal Knoxville beds, as described by Dr. H. W. Fairbanks.[1] The lowest Knoxville may be assigned to the Jurassic.

Second: The species from Slate's Springs are very similar, and in five instances out of seven are practically identical with described Jurassic forms. None of the species are unlike Jurassic forms. The *Alaria* shows that the beds are probably not pre-Jurassic.

Third: Five of the seven species listed from Slate's Springs are identical, or nearly identical with species described from the Queen Charlotte Islands. The Queen Charlotte Islands beds have been definitely correlated by Stanton[2] with the Enochkin formation of Alaska, which is called (Upper) Middle Jurassic.

Finally: The foregoing facts seem to place the Slate's Springs (Franciscan) beds not higher than the lower Upper Jurassic.

[1] "Geology of the Southern Coast Ranges," *Jour. Geol.*, VI (1898), 551–76.

[2] "Mesozoic Section on Cook Inlet and Alaska Peninsula," *Bull Geol. Soc. Am.*, XVI, 391–410.

GLACIAL POT-HOLES AT CROWN POINT, NEW YORK

E. EUGENE BARKER
Cornell University

Glacial pot-holes have been described from various parts of the glaciated regions of North America and Europe. They occur singly or in groups, in positions unrelated to the beds of modern streams. Perhaps the best-known examples are in the famous Glacier Garden at Lucerne in Switzerland, where they are seen by many tourists every year. Even more remarkable than this most advertised occurrence is a small area on the Dalles of the St. Croix River near Taylor's Falls, Minn., described in detail by Upham (31). He says it is "unsurpassed by any other known locality in respect to the variety of forms and grouping, their great number and extraordinary irregularity of contour." In all, there occur within the area not fewer than 100, large and small.

The purpose of this note is to call attention to and describe a very fine specimen of glacial pot-hole that has been discovered recently at a place of commanding historic interest—Crown Point on Lake Champlain, a long promontory of horizontally bedded limestone jutting northward into the lake. Because of its great strategic importance this point was fortified by the French in 1731. Fort St. Frédéric, the stronghold they built, was captured and destroyed by the British under General Amherst in 1759. Immediately afterward, Amherst built the great star-shaped fortress with ramparts extending half a mile in circumference, whose ruins now attract thousands of visitors annually. In the summer of 1912, while these ruins were being explored and reinforced by the state government, the pot-hole here described was discovered.

Fig. 1 shows the pot-hole with the ruins of the soldiers' barracks and a portion of the ramparts in the background. It extends to a depth of 14 feet 7 inches into the topmost strata of the Chazy limestone formation. The aperture at the surface is an irregular oblong measuring 6 feet 4 inches by 9 feet 7 inches. The longer

FIG. 1.—Glacial pot-hole at Fort Crown Point. Ruins of soldiers' barracks, with a bit of the encircling ramparts, and a glimpse of Lake Champlain in the background. (Copyright 1913 by E. E. Barker.)

FIG. 2.—Glacial pot-hole, at Fort Crown Point. Looking in from above

axis coincides with a joint-plane. The pot-hole shows four stages of grinding, each deeper than the preceding, excentric to it, and somewhat larger in diameter (Fig. 2). The first and shallowest is farthest to the north. This might indicate that during the first stages of its formation the ice mass was moving southward. Its greatest diameter is 7 feet 4 inches, and is found just below the second shoulder. Beyond this the deep cylindric bore is attained. The inside surface is very smooth in places, but in part is marked with a low relief of ridges due to differential erosion of the harder and softer portions of the rock (Fig. 3). The pot-hole, when discovered, was filled with its original content of glacial débris intact. Many wagon loads of this material, consisting of large bowlders smoothly rounded, smaller cobblestones, with a filling of gravel and sand, were removed and piled in a cairn near by. They are mostly crystalline rocks, and are of great variety, representing nearly all of the formations found in the region to the north. The large bowlder that lay in the apex of the hole, together with two beautifully rounded smaller ones that lay on either side of it, has been preserved. The largest is shown just inside the railing in Figs. 1 and 3. These stones were evidently the active tools of the glacial torrent at the time when grinding ceased and the hole became clogged with the mass of débris with which it was filled. The surface of the surrounding rock is planed smooth and is scored with glacial striae.

Another glacial pot-hole occurs on Towner Hill, about six miles west from Lake Champlain, and about eight or ten miles southwest from the locality described above. This pot-hole was filled with ice when the photograph was taken, but it is said to be 8 or 10 feet deep (Fig. 4). At the surface of the ice its diameter measured 5 feet by 4 feet 4 inches. Its original depth must have been considerably greater, because it has suffered erosion since its formation that has truncated it obliquely to its perpendicular axis. The rear wall rises 5 feet 6 inches above the surface of the ice that filled it to the lowest portion of the rim at the time it was seen (Fig. 4). It is located half-way down the face of a cliff of hard gneiss at an altitude of about 1,260 feet according to the U.S. Geological Survey sheet (Paradox Lake Quadrangle, N.Y.). The

FIG. 3.—Glacial pot-hole at Fort Crown Point, showing irregular aperture, ridged inner surface, and the principal grinding-stone.

FIG. 4.—Glacial pot-hole on Towner Hill, Crown Point, N.Y.

rim is smoothed and rounded off, and it has unmistakably undergone great erosion and weathering since it was bored.

At the foot of the cliff is the remnant of a still larger pot-hole that now forms a shallow niche in the face of the cliff, and comprises the arcs of two intersecting circles with a combined diameter of 12 to 15 feet for the original pot-hole. The diameter of the smaller arc is computed to be 6.12 feet. Its depth is unknown, as it has never been cleared of the débris that fills it.

Upham (31) describes a pot-hole in the Interstate Park at Taylor's Falls in every way similar to this latter one. He suggests the hypothesis that it was formed partly in rock and partly in ice, and that when the ice melted away it was left in the imperfect form seen at present. The pot-hole described here, however, because of its proximity to another that shows unmistakable evidence of erosion, would seem to favor the hypothesis that it was bored in solid rock, and that, subsequently, the greater portion of it had been eroded away. Both pot-holes occur nearly at the top of a mountain, and are far from any stream bed. Their partial demolition after their formation supports Upham's hypothesis that such pot-holes were formed during the early stages of the ice-sheet; but they can be equally well explained by the advance of a later ice invasion.

March 17, 1913.

BIBLIOGRAPHY

1. Ashburner, C. A. *Geol. Survey of Penn.*, Ann. Rept. for 1885, pp. 615-25.
2. Bachman, —. *Neues Jahrb.*, p. 53, 1875.
3. ———. *Preuss. Geol. Landesanst. Jahrb.*, p. 275, 1880.
4. Bonney, T. G. *Ice Work, Present and Past*, pp. 34–35, 1896.
5. ———. *Story of Our Planet*, 1893.
6. Bouvé, T. T. "Indian Pot-Holes or Giants' Kettles of Foreign Writers," *Boston Soc. of Nat. Hist., Proc.*, XXIV, 219–26, 1889.
7. Brögger, W. C., and Reusch, H. H. *Geol. Soc. of London, Quar. Jour.*, XXX, 750–71, 1874.
8. Crosby, W. O. "Geology of the Boston Basin," *Boston Soc. of Nat. Hist., Occasional Papers*, IV, Vol. I, pp. 148–59, 1893.
9. ———. "Geological History of the Nashua Valley during the Tertiary and Quaternary Periods," *Technology Quarterly*, XII, 318, 1899.
10. Dana, J. D. *Manual of Geology*, 4th ed., p. 949, 1895.
11. Britton, N. L. *N.Y. Acad. Sci., Trans.*, I, 181–83, 1882.

12. Emmons, E. *Geol. of New York*, Pt. II, Surv. of Second Geol. Dist., pp. 410, 411, 424, 1842.
13. Emmons, S. F. *U.S. Geol. Surv.* (quoted by Wright, p. 36).
14. ———. *Geol. of New Hampshire*, III, 1878.
15. Geikie, Sir A. *Textbook of Geology*, p. 429, 1893.
16. ———. *Great Ice Age and Its Relation to the Antiquity of Man*, p. 50, 1894.
17. Hershey, O. H. *Science*, N.S., X, 58, 1899.
18. ———. *Ibid.*, X, 88, 187, 298, 1899.
19. Hitchcock, C. H. *Geol. of New Hampshire*, III, 64–66, 249, 250, 1878.
20. ———. *Geol. of Vermont*, pp. 216, 217, 763, 930, 933, 1861.
21. Hitchcock, E. and C. H. *Geol. of Vermont*, pp. 216–17, 1861.
22. Hubbard, O. P. *N.Y. Acad. Sci., Trans.*, IX, 3, 1890.
23. Jackson, C. T. *Geol. of New Hampshire, Final Rept.*, pp. 113, 114, 282, 1844.
24. Koons, B. F. *Am. Jour. Sci.*, 3d series, XXV, 471, 1883.
25. Lubbock, Sir J. *Scenery of Switzerland*, p. 133, 1896 (quotes Favre in *Rech., Geol.*, V, 1.)
26. Merrill, G. P. *Smithsonian Institution, Miscellaneous Collections, Quarterly Issue*, No. 1427, XLV, 1903.
27. Sexe, S. A. *Universit. Christiania, Program*, 1874.
28. Stone, G. H. *Am. Jour. Sci.*, 4th series, IX, 9–12, 1900.
29. ———. "Glacial Gravels of Maine and Their Associated Deposits," *U.S. Geol. Surv., Monograph 34*, pp. 324–30, 1899.
30. Upham, W. "Giants' Kettles near Christiania and in Lucerne," *Am. Geol.*, XXII, 291–99, 1898.
31. ———. "Giants' Kettles Eroded by Moulin Torrents," *Geol. Soc. of Am., Bull. 12*, pp. 25–44, 1900.
32. ———. *Boston Soc. of Nat. Hist., Proc.*, XXIV, 219–26, 226–28, 1889.
33. ———. *Hitchcock's Geol. of New Hampshire*, III, 64–66, 249, 1878.
34. von Engeln, O. D. "Phenomena Associated with Glacier Drainage and Wastage, with Especial Reference to Observations in the Yakutat Bay Region, Alaska," *Zeit. f. Gletscherkunde*, VI, 104–50, 1911.
35. Woodworth, J. B. "Ancient Water Levels between the Champlain and Hudson Valleys," *N.Y. State Mus., Bull. 84*, 1905.
36. Wright, C. F. *Ice Age in America and Its Bearing on the Antiquity of Man*, p. 9, 22, 44, 1889.

Reviews

C. Doelter, ***Handbuch der Mineralchemie*** **Band I. (Dresden und Leipzig: Theodor Steinkopff. M. 45.)**

The need of a standard work of reference dealing more particularly with the advances made during the last twenty years in our knowledge of mineral statics has been in recent years a very pressing one. The works of Vogt, Tscherwinsky, Doelter, Van Hise, Harker, Elsden, and Clarke have each taken up certain aspects of the subjects, but exhaustive treatment was impossible within the limits imposed. The appearance of the first volume of Doelter's *Handbuch* is, however, sufficient surety that such a work is now to be provided. But it is today no longer possible for one writer to cover the whole field of mineral chemistry, and it has been found desirable in the work under consideration to obtain the services of some 58 contributors, in order especially to insure that the four volumes shall appear within a reasonably short space of time, and consequently at one particular stage in the development of the subject. While the plan leads to a certain amount of overlapping—not in itself necessarily an evil—it has the great advantage that no part of the subject is left untouched, and that every aspect is handled by an authority in that particular field. And in this connection one cannot fail to remark on the fortunate position in which the editor was placed in that he could draw so fully on the resources of the Vienna school.

In two aspects in particular the work represents a marked advance on the older treatises of Rammelsberg and Hintze. The technical application of minerals and mineral materials receives full treatment. Thus in the volume already issued articles appear on the industrial uses of magnesite, on cement, glass, glazes, and enamels. These subjects are discussed in their physicochemical and mineralogical bearing, and the two articles on cement and Zschimmer's exhaustive paper on glass form valuable statements of the results of recent investigations on subjects which are intimately connected with the sciences of mineralogy and petrology. But the dominant line of progress at the present time is the elucidation, largely from the experimental standpoint, of the genesis and stability conditions of minerals that play an important rôle as rock-formers, no matter whether they form from silicate fusion or from aqueous solution. The name of the editor has long been associated with

this line of investigation, and it is from this standpoint in particular that the *Handbuch* will be considered the authoritative work of reference. Consequently it is not merely a treatise on mineral chemistry. It cannot fail to deal as well with the most fundamental problems of petrogenesis.

Some difficulty has been experienced in arriving at an entirely satisfactory arrangement of the material. The older classification of Groth, in which the elements that occur as minerals are first disposed of, has been discarded, and an arrangement has been adopted which is based on, but does not follow in complete detail, the periodic classification of the elements. Thus in the volume now before us carbon and its compounds are first dealt with, and the treatment of silicon and of some of the general aspects of the silicates then follows. Out of some 150 articles it is perhaps invidious to single out any particular cases, as the selection inevitably depends materially on the subjects in which the reviewer is specially interested. Two of the features of the first volume to which the writer has given more careful attention are the articles on the carbonates by Leitmann, and Doelter's paper on silicate melts. Leitmann in a long series of articles has dealt with the naturally occurring anhydrous carbonates, and has handled a literature of enormous proportions with marked judgment and reserve. Particularly valuable are the discussions on synthesis and processes of formation in nature, and the physico-chemical treatment of the solubilities. It is part of the plan of the *Handbuch* to introduce a broad division of the minerals by an article dealing with the whole or part of the field from the comparative standpoint: and Linck's suggestive article on the carbonates of lime, iron, and magnesia summarizes the work of the Jena school on the stability conditions of these compounds as they occur in nature.

Doelter's contributions to this volume deal with the formation of graphite, the carbonates, phosgenite, silicon, the synthesis of the silicates, and silicate fusions. The last is an article of almost 200 pages, which reviews the whole field and emphasizes the lines of investigation at present being pursued. On some points in this paper there will be a decided difference of opinion. While it cannot be doubted that Doelter's insistence on the registration of two temperatures on the fusion curve gives a much-needed emphasis to the fact that silicates react with remarkable slowness, the methods on which he has chiefly relied can hardly be considered to have been so fruitful in the interpretation of two-component systems as the methods of thermal analysis applied by Tammann and his school to the alloys and later to the silicates, or as used

in somewhat different form with such marked success in the Carnegie Institute of Washington. One cannot but feel that Doelter's attitude with reference to some of the work of the American school is unfortunate. Of particular interest, however, are the sections on electrical conductivity, on specific heat and latent heat of fusion, and on the relation of the whole subject to rock crystallization and differentiation. While certain parts of the article are to be found in Doelter's earlier books, it is by far the most complete and valuable résumé of the subject of silicate fusions that we yet possess.

The services of Dittrich have been secured to deal with methods of analysis of the various classes of minerals. Vogt contributes an article on slags, and treats the subject rather more from the standpoint of the metallurgist than in his previous works with which petrologists are acquainted. It need only be added that the publishers seem to have fully realized the value of the *Handbuch*, and have spared no pains to make it a most attractive addition to a reference library. May the other three volumes very soon find their place beside this one on the library shelves.

R. C. WALLACE

An Introduction to the Mathematical Theory of Heat Conduction, with Engineering and Geological Applications. By L. R. INGERSOLL and O. J. ZOBEL. Boston: Ginn & Co., 1913. Pp. 171, 24 figs.

Although primarily intended for students of physics, this textbook contains, as its subtitle would suggest, a certain amount of material that has an important bearing on geological problems, especially those that have to do with the transfer of heat. In chap. vii, on "The Linear Flow of Heat," some of the sections bearing on geology are: thawing of frozen soil, cooling of lava under water, cooling of the earth with and without radioactive considerations, and estimates of age, heat sources, temperatures in decomposing granite. Chap. viii, "The Flow of Heat in More than One Dimension," treats the cooling of a laccolith and the cooling of a sphere by radiation.

The conclusions on the nature and rate of progress of a heat wave traveling from a laccolith into limestone throw interesting light on the conditions of the contact metamorphism of limestone and the development of ores at such points. The slow advance of the heat wave, allowing as it does a difference of temperature of about 50° C. at points 200 meters on either side of the contact, at the end of 10,000 years, must be a

very important factor controlling the work of underground waters. Again, this same process demands, first the development of a compressional condition in the limestone, followed later by a period of tensional stresses as the rock cools. Accordingly, the compressional phase advances like a wave normal into the limestone, followed by a tensional phase which tends to produce fissures. This accords with the facts observable at limestone contacts. Chap. ix deals with the conditions of the formation of ice.

The handling of the problems in each case is highly mathematical as the title of the book would suggest, but the results obtained may be somewhat readily applied to many concrete cases in geological science.

W. L. U.

Recent Publications

—Abele, C. A. Statistics of the Mineral Production of Alabama for 1910. Compiled from Mineral Resources of the United States. [Geological Survey, Alabama, Bulletin 12. Montgomery, 1912.]

—Allen, E. T., and Crenshaw, J. L. The Sulphides of Zinc, Cadmium and Mercury; Their Crystalline Forms and Genetic Conditions. [American Journal of Science, Vol. XXXIV, October, 1912.]

—Allen, I. C. Specifications for the Purchase of Fuel Oil for the Government with Directions for Sampling Oil and Natural Gas. [Department of the Interior, Bureau of Mines Technical Paper 3. Washington, 1911.]

—Allen, Irving C., and Robertson, I. W. Methods of Determining the Sulphur Content of Fuels, Especially Petroleum Products. [Bureau of Mines Technical Paper 26. Washington, 1912.]

—American Association of Museums, Proceedings of the Records of the Fifth Annual Meeting Held at Buffalo, N.Y., May 31–June 2, 1910. [Charleston, S.C., 1911.]

—American Journal of Science, Fourth Series. Vol. XXXIV, No. 202. [New Haven, October, 1912.]

———. Vol. XXXIV, No. 203. [New Haven, November, 1912.]

—American Museum of Natural History, Forty-third Annual Report of. For the Year 1911. [New York, February 5, 1912.]

—American Philosophical Society, List of the. [Philadelphia, August, 1912.]

———. Proceedings of the. Vol. LI, No. 205 (July, 1912). [Philadelphia, 1912.]

—Bagg, R. M. Pliocene and Pleistocene Foraminifera from Southern California. [U.S. Geological Survey Bulletin 513. Washington, 1912.]

—Bain, H. F. (Editor). Types of Ore Deposits. [San Francisco: Mining and Scientific Press, 1911.]

—Barrow, George, F.G.S., and Cunningham Craig, E. H., B.A., F.G.S.; with contributions by Hinxman, L. W., B.A., F.R.S.E. The Geology of the Districts of Braemar, Ballater, and Glen Clova. Explanation of Sheet 65, Memoirs of the Geological Survey, Scotland. [Edinburgh, 1912.]

—Barrows, H. K., and Babb, C. C. Water Resources of the Penobscot River Basin, Maine. [U.S. Geological Survey Water-Supply Paper 279. Prepared in co-operation with the Maine State Survey Commission. Washington, 1912.]

—Bayley, W. S. Iron Mines and Mining in New Jersey. (Vol. VIII of the Final Report Series of the State Geologist.) [New Jersey Geological Survey. Trenton, 1910.]

—BECK, K. Petrographisch-geologische Untersuchung des Salzgebirges im Werra-Fulda-Gebiet der deutschen Kalisalzlagerstätten. [Sonderabdruck aus der Zeitschrift für praktische Geologie, XX, Jahrgang, 1912, Heft 4. Verlag von Julius Springer in Berlin W. 9.]

—BENEDICT, FRANCIS G. The Composition of the Atmosphere, with special Reference to Its Oxygen Content. [Carnegie Institution of Washington. Washington, D.C., 1912.]

—BIRGE, E. A., AND JUDAY, C. The Inland Lakes of Wisconsin. The Dissolved Gases of the Water and Their Biological Significance. [Wisconsin Geological and Natural History Survey Bulletin, XXII. Scientific Series No. 7. Madison, 1911.]

—BOWEN, N. L. The Binary System: $Na_2Al_2Si_2O_8$ (Nephelite, Carnegieite) —$CaAl_2Si_2O_8$ (Anorthite). [From the American Journal of Science, Vol. XXXIII, June, 1912.]

—BOWMAN, I. Forest Physiography: Physiography of the United States and Principles of Soils in Relation to Forestry. [New York: John Wiley & Sons, 1911.]

—BRECKINRIDGE, L. P., KREISINGER, H., AND RAY, W. T. Steaming Tests of Coals and Related Investigations. September 1, 1904, to December 31, 1908. [Bureau of Mines Bulletin 23. Washington, 1912.]

—BRIDGMAN, P. W. Thermodynamic Properties of Liquid Water to 80° and 12,000 Kgm. Proceedings of the American Academy of Arts and Sciences, Vol. XLVIII, No. 9. [September, 1912.]

—BROOKS, A. H. The Alaska Mining Industry in 1911, and Railway Routes in Alaska. [U.S. Geological Survey Bulletin 520-A. Washington, 1912.]

———. The Mount McKinley Region, Alaska. With Descriptions of the Igneous Rocks and of the Bonnifield and Kantishna Districts, by L. M. PRINDLE. [U.S. Geological Survey Professional Paper 70. Washington, 1911.]

—BRUCE, WILLIAM S., LL.D., F.R.S.E. The Area of Unknown Antarctic Regions Compared with Australia, Unknown Arctic Regions, and British Isles. [Scottish Oceanographical Laboratory, Surgeon's Hall, Edinburgh.]

———. The Oceanographical Institute at Paris. [Reprinted from Nature, February 16, 1911.]

———. The Prince of Monaco and Oceanographical Research. [Scottish Oceanographical Laboratory, Surgeon's Hall, Edinburgh.]

—BRUNHES, J., CHAIX, E., AND MARTONNE, EMM. DE. Atlas photographique des formes du relief terrestre. Documents morphologiques caractéristiques avec notices scientifiques. [Publiés conformément à un voeu du IX^e^ Congrès international de géographie sous les auspices d'une Commission internationale permanente. Éditeurs: Fréd. Boissonnas et Cie. Genève, 1911.]

—BUCKMAN, H. O. The Chemical and Physical Processes Involved in the Formation of Residual Clay. [Transactions of the American Ceramic Society, Vol. XIII, 1911.]

—BUCKMAN, S. S. (Editor). Yorkshire Type Ammonites. Part. V. 10 Plates, and Descriptions. Nos. 38–44. [London: William Wesley & Son, 28 Essex St., Strand, 1911.]

—BUCKMAN, S. S., AND TUTCHER, J. W. Yorkshire Type Ammonites. Part VII. 9 Plates, and Descriptions Nos. 52–60. [London: William Wesley & Son, 28 Essex St., Strand, 1912.]

—Bureau of Soils. A Beneficial Organic Constituent of Soils: Creatinine. [U.S. Department of Agriculture, Bureau of Soils Bulletin 83. Washington, 1911.]

—BURR, CHARLES H. The Treaty-making Power of the United States and the Methods of Its Enforcement as Affecting the Police Powers of the States. [Proceedings of the Amer. Philosophical Society, Philadelphia, August–September, 1912.]

—BURRELL, S. A. The Use of Mice and Birds for Detecting Carbon Monoxide after Mine Fires and Explosions. [U.S. Bureau of Mines Technical Paper 11. Washington, 1912.]

—BURRELL, S. A., AND SEIBERT, F. M. Gas Analysis as an Aid in Fighting Mine Fires. [U.S. Bureau of Mines Technical Paper 13. Washington, 1912.]

—BUTLER, B. S., AND GALE, H. S. Alunite, a Newly Discovered Deposit near Marysvale, Utah. [U.S. Geological Survey Bulletin 511. Washington, 1912.]

—Butlletí del Club Montanyenc. Associació de Ciencies Naturals i Excursións. Any I. Barcelona, Abril–Maig, 1912. Ne. 4–5.

—Cape of Good Hope Department of Mines. Fifteenth Annual Report of the Geological Commission. 1910. [Cape Town, 1911.]

—CLARK, H. H. The Electrical Section of the Bureau of Mines. Its Purpose and Equipment. [Department of the Interior, Bureau of Mines Technical Paper 4. Washington, 1911.]

———. Electrical Symbols for Mine Maps. [Bureau of Mines Technical Paper 22. Washington, 1912.]

—CLARK, W. B., AND MILLER, B. LeR. The Physiography and Geology of the Coastal Plain Province of Virginia. With chapters on The Lower Cretaceous, by EDWARD W. BERRY, and The Economic Geology, by THOMAS LEONARD WATSON. [Virginia Geological Survey Bulletin IV. Charlottesville, 1912.]

—CLARKE, EDWARD DECOURCY. The Geology of the New Plymouth Subdivision, Taranaki Division. [Geological Survey Branch, New Zealand Department of Mines Bulletin 14 (New Series). Wellington, 1912.]

—CLELAND, H. F. The Fossils and Stratigraphy of the Middle Devonic of Wisconsin. [Wisconsin Geological and Natural History Survey Bulletin XXI. Scientific Series No. 6. Madison, 1911.]

—Colorado School of Mines Magazine. [The Colorado School of Mines Alumni Association, Publishers, Golden, Colo. September, 1912.]

—Concrete, Vol. XII, No. 2, February, 1912. [Detroit, Mich.: Concrete Publishing Co.]

—COPELAND, D., MANN, H. T., AND ROESLER, H. A. Metallurgical and Ore Dressing Laboratories of the Missouri School of Mines and Metallurgy. [Bulletin of the School of Mines and Metallurgy, University of Missouri, Vol. I, No. 2, Rolla. February, 1912.]

—CRAIG, E. H. C. Oil-Finding. An Introduction to the Geological Study of Petroleum. With an Introduction by Sir Boverton Redwood. [New York: Longmans, Green & Co., 1912.]

—CRANE, G. W. The Iron Ores of Missouri. [Missouri Bureau of Geology and Mines, Vol. X, Second Series. Jefferson City, 1912.]

—CROOK, A. R., PH.D. Geology of Sangamon County. [Springfield, Ill., 1912.]

———. The Training of Museum Curators. [Reprinted from the Proceedings of the American Association of Museums, Vol. IV, 1910.]

—DAVISON, C. The Origin of Earthquakes. [New York: Putnam, 1912.]

—DAY, ARTHUR L., AND SOSMAN, ROBERT B. The Expansion Coefficient of Graphite. [Reprinted from the Journal of Industrial and Engineering Chemistry, Vol. IV, No. 7, July, 1912.]

—DERBY, ORVILLE A. Bibliographical List of the Scientific Publications of. Typographia Leuzinger. [Rio de Janeiro, 1908.]

—DILLER, J. S., AND OTHERS. Advance Chapter from Contributions to Economic Geology (Short Papers and Preliminary Reports), 1910. Part I. Metals and Nonmetals except Fuels. Gold and Silver. [U.S. Geological Survey Bulletin 470-B. Washington, 1911.]

—DUNSTAN, C. E. Preliminary Examination of the Forest Conditions of Mississippi. [Mississippi Geological Survey Bulletin 7. Jackson, Miss., 1910.]

—DU TOIT, A. L. Geological Map of the Province of the Cape of Good Hope. Sheet XXVI. [Geological Commission. Cape Town, 1912.]

—ECKEL, E. C. Building Stones and Clays: Their Origin, Characters and Examination. [New York: John Wiley & Sons, 1912.]

—ELLIS, DON CARLOS. A Working Erosion Model for Schools. U.S. Department of Agriculture Circular 117. Washington, 1912.]

—EMMONS, W. H., AND LARSEN, E. S. A Preliminary Report on the Geology and Ore Deposits of Creede, Colorado. [U.S. Geological Survey Bulletin 530-E. Washington, 1912.]

—Escola de Minas de Ouro Preto, Annaes da. N. 11, 1909. [Typographia Machado, 8, Rua Tiradentes, Ouro Preto.] N. 12, 1910. [Ouro Preto: Typ. d'O Regenerador.]

—EVANS, G. W. The Coal Fields of King County. [Washington Geological Survey Bulletin 3. Olympia, 1912.]

—FARIS, R. L. Terrestrial Magnetism, Results of Magnetic Observations Made by the Coast and Geodetic Survey between July 1, 1910, and June 30, 1911. Appendix No. 3—Report for 1911. [Department of Commerce and Labor, Coast and Geodetic Survey. Washington, 1912.]

—FARRELL, J. H. Practical Field Geology. Including a Guide to the Sight Recognition of One Hundred and Twenty Common or Important Minerals by ALFRED J. MOSES. [New York and London: McGraw-Hill Book Co., 1912.]

—First Commercial Gas Company to Sell Gas as an Illuminant, Lectures Delivered at the Centenary Celebration of the. Held at the Franklin Institute, Philadelphia, Pa., April 18 and 19, 1912. [New York: American Gas Institute, 29 W. 39th St.]

—FISHER, W. L. Alaskan Coal Problems. [U.S. Geological Survey Bureau of Mines Bulletin 36. Washington, 1912.]

—FOLLANSHEE, R., HORTON, A. H., AND STEVENS, G. C. Surface Water Supply of the United States, 1910. Part V. Hudson Bay and Upper Mississippi River. Prepared under the direction of M. O. LEIGHTON. [U.S. Geological Survey Water-Supply Paper 285. Washington, 1912.]

—FREER, P. C. Tenth Annual Report of the Director of the Bureau of Science to the Honorable the Secretary of the Interior, for the Year ending August 1, 1911. [Manila: Bureau of Printing, 1912.]

—FRIEDLAENDER, IMMANUEL. Über die Wärmeleitung einiger vulkanischer Gesteine. [Sonderabdruck aus Gerlands Beiträgen zur Geophysik. Herausgegeben von Prof. Dr. O. Hecker und Prof. Dr. E. Rudolph. XI Band, 2–4, Heft. Leipzig: Verlag von Wilhelm Englemann, 1912.]

—FULLER, M. L. The New Madrid Earthquake. [U.S. Geological Survey Bulletin 494. Washington, 1912.]

—GEE, L. C. E. (Compiler). The Occurrence of Uranium (Radio-Active), Ores and Other Metals and Minerals in South Australia. [South Australia Department of Mines. Adelaide, 1911.]

———. A Review of Mining Operations in the State of South Australia during the Half-Year Ended December 31, 1911. No. 15. [South Australia Department of Mines. Adelaide, 1912.]

—GEE, LIONEL C. E., S.M. A Review of Mining Operations in the State of South Australia during the Half-Year Ended June 30, 1912. No. 16. [Adelaide, 1912.]

—Geographischer Literaturbericht, Mai 1912. [Petermanns Geogr. Mitteilungen, 1912.]

—Geological Society, The Quarterly Journal of the. Vol. LXVIII, No. 271. Part 3. [London: Longmans, Green & Co.]

—Gilmore, C. W. The Mounted Skeletons of *Camptosaurus* in the United States National Museum. [No. 1878, Proceedings of the U.S. National Museum, Vol. XLI, pp. 687–96, with Plates 55–61. Washington: Government Printing Office, 1912.]

———. A New Mosasauroid Reptile from the Cretaceous of Alabama. [No. 1870, Proceedings of the U.S. National Museum, Vol. XLI, pp. 479–84, with Plates 39–40. Washington, January 31, 1912.]

—Gilpin, J. E., and Bransky, O. E. The Diffusion of Crude Petroleum through Fuller's Earth with Notes on Its Geologic Significance. [U.S. Geological Survey Bulletin 475. Washington, 1911.]

—Goodale, George Lincoln. Biographical Memoir of Alexander Agassiz. 1835–1910. [Published by National Academy of Sciences. Washington D.C.]

—Gordon, C. H. The Marbles of Tennessee. [Extract [D] from Bulletin 2, "Preliminary Papers on the Mineral Resources of Tennessee." Tennessee Geological Survey. Nashville, 1911.]

—Goss, W. F. M. Comparative Tests of Run-of-Mine and Briquetted Coal on Locomotives, Including Torpedo-Boat Tests and Some Foreign Specifications for Briquetted Fuel. [Bureau of Mines Bulletin 37. Reprints of U.S. Geological Survey Bulletin 363. Washington, 1912.]

—Gratacap, L. P. A Popular Guide to Minerals. [New York: D. Van Nostrand Co., 25 Park Place, 1912.]

—Gregory, J. W. Geology. [Appleton's Scientific Primers. New York: D. Appleton & Co.]

—Gunther, C. G. The Examination of Prospects. A Mining Geology. [New York and London: McGraw-Hill Book Co., 1912.]

—Häberle, D. Ueber einen durch Blitzschlag verursachten Felsabsturz im Mittelgebirge. [Sonderabdruck aus den Jahresberichten und Mitteilungen des oberrheineschen geologischen Vereines. Neue Folge, Bd. II, Heft 3, Seite 26–29. Karlsruhe: J. Langs Buchdruckerei, 1912.]

———. Die Mineralquellen der Rheinpfalz. [Sonderabdruck aus dem Wanderbuch des Pfälzerwald-Vereins für 1912. Kaiserslautern: Hermann Kayser's Verlag, 1912.]

———. Jahres-Berichte und Mitteilungen des Oberrheinischen geologischen Vereines. Neue Folge. Bd. 2. Jahrgang 1912. Heft 2. Mit Programm und Führer für die am 9. April 1912 zu Rheinfelden stattfindende 45. Versammlung. [In Kommission bei der E. Schweizerbartschen Verlagsbuchhandlung Nägele und Dr. Sproesser. Stuttgart, März, 1912.]

—Hall, C. Permissible Explosives Tested Prior to January 1, 1912, and Precautions to Be Observed in Their Use. [U.S. Geological Survey Miners' Circular 6, Bureau of Mines. Washington, 1912.]

—HALL, M. R., AND MATHERS, J. G. Surface Water Supply of the United States, 1910. Part II. South Atlantic Coast and Eastern Gulf of Mexico. [U.S. Geological Survey Water-Supply Paper 282. Washington, 1912.]

—Handbuch der Mineralchemie. 1. Band, 4. Abteilung. 1. Band, 5. Abteilung. [Dresden: Verlag von Theodor Steinkopff, 1911.]

—HANDLIRSCH, A. New Paleozoic Insects from the Vicinity of Mazon Creek, Illinois. [From the American Journal of Science, Vol. XXXI, April–May, 1911.]

—HAY, O. P. On an Important Specimen of *Edestus;* with Description of a New Species, *Edestus mirus*. [No. 1884. From the Proceedings of the U.S. National Museum, Vol. XLII. Washington, April 25, 1912.]

—HAYES, C. W., AND LINDGREN, WALDEMAR. Contribution to Economic Geology (Short Papers and Preliminary Reports), 1910. Part I. Metals and Nonmetals Except Fuels. [U.S. Geological Survey Bulletin 470. Washington, 1911.]

—HESS, F. L., HEWETT, D. F., LARSEN, E. S., AND HUNTER, J. F. Sulphur in Utah, Wyoming and Colorado. [Bulletin 530-O. Washington, 1912.]

—HILL, J. M. The Mining Districts of the Western United States. With an Introduction by Waldemar Lindgren. [U.S. Geological Survey Bulletin 507. Washington, 1912.]

—HÖFER, DR. H. C. HANS, VON HEIMHALT. Grundwasser und Quellen, eine Hydrogeologie des Untergrundes. [Braunschweig: Druck und Verlag von Friedr. Vieweg und Sohn, 1912.]

—HOWCHIN, W. Cambrian and Permo-Carboniferous Glaciation. [Australasian Association for the Advancement of Science, Vol. XIII. Sydney, April 23, 1912.]

———. On an Outlier of Older Cainozoic Rocks in the River Light Near Mallala. [Transactions of the Royal Society of Southern Australia, Vol. XXXVI, 1912.]

—Illinois State Museum of Natural History, Report on the Progress and Condition of the. For the Years 1909 and 1910. [Springfield, June, 1911.]

—Jahres-Berichte und Mitteilungen des Oberrheinischen geologischen Vereins. Neue Folge. Bd. 1. Jahrgang 1911. (Bisher Berichte über die Versammlungen des Oberrheinischen Vereines.) Heft 2. (Mit dem Bericht über die 44. Versammlung zu Schramberg am 18. April 1911.) [Stuttgart, 1911.]

———. Neue Folge. Bd. 2. Jahrgang 1912. Heft 3. [Stuttgart, 1912.]

—JAMISON, C. E. The Douglas Oil Field, Converse County, Wyoming. The Muddy Creek Oil Field, Carbon County, Wyoming. [Wyoming Geological Survey Bulletin 3, Series B. Cheyenne, 1912.]

———. Geology and Mineral Resources of a Portion of Fremont County, Wyoming. [Geological Survey of Wyoming Bulletin 2, Series B. Cheyenne, 1911.]

—JENNISON, WILLIAM F. Report on the Gypsum Deposits of the Maritime Provinces. [Canada Department of Mines, Mines Branch No. 84. Ottawa, 1911.]

—KEELE, J. The Effect of Feldspar on Kaolin in Burning. [Transactions of the American Ceramic Society, Vol. XIII, 1911.]

—KEMP, J. F. Comparative Sketch of the Precambric Geology of Sweden and New York. With Notes on the Geology of the Swedish Magnetites by D. H. NEWLAND. [From New York State Museum Bulletin 149, Seventh Report of the Director, State Museum, 1910. Albany, 1911.]

———. The Mineral Springs of Saratoga. [New York State Museum Bulletin 159. Education Department Bulletin 517. Albany, April 15, 1910.]

—KENT, NORTON A. A Study with the Echelon Spectroscope of Certain Lines in the Spectra of the Zinc Arc and Spark at Atmospheric Pressure. [Proceedings of the American Academy of Arts and Sciences. Vol. XLVIII, No. 5. August, 1912.]

—KEYES, C. R. Graphics of Ore-Origin; Volcanic Phenomena of Coon Butte Region, Arizona (Abstract); and Depositional Phases of Eolation under the Stimulus of Aridity (Abstract). [Iowa Academy of Science, 1912.]

———. Relations of Missouri River Loess Mantle and Kansan Drift-Sheet. [American Journal of Science, Fourth Series, Vol. XXXIII, No. 193, January, 1912.]

———. Wind-graved Mesas and Their Message. [Popular Science Monthly, September, 1912.]

—KIRK, E. The Structure and Relationship of Certain Eleutherozoic Pelmatazoa. [No. 1846. From the Proceedings of the U.S. National Museum, Vol. XLI, pp. 1–137, with Plates 1–11. Washington: Government Printing Office, June 7, 1911.]

—KNOPF, A. The Sitka Mining District, Alaska. [U.S. Geological Survey Bulletin 504. Washington, 1912.]

—Königlich ungarischen geologischen Reichsanstalt für 1908, Jahresbericht der. Übertragung aus dem ungarischen Original. (Ungarisch erschienen im September, 1910.) [Budapest: Druck des Franklin-Vereins, 1911.]

—KRAMM, H. E. Some Effects of Gypsum on Clay. [Transactions of the American Ceramic Society, Vol. XIII, 1911.]

—KRAUS, E. H., COOPER, H. C., UND KLEIN, A. A. Die optischen Eigenschaften einiger Bleisilikate. [Separat-Abdruck aus dem Centralblatt f. Min., etc., Jahrg. 1912, No. 10.]

—KREBS, C. E. Jackson, Mason and Putnam Counties. (With accompanying geologic, topographic and soil maps.) [Report of West Virginia Geological Survey. Morgantown, 1911.]

—KREISINGER, H., AND RAY, W. T. The Transmission of Heat into Steam Boilers. [U.S. Bureau of Mines Bulletin 18. Washington, 1912.]

—LAMB, W. A., FREEMAN, W. B., RICHARDS, R., AND RICE, R. C. Surface Water Supply of the United States, 1910. Part VI. Missouri River

Basin. Prepared under the direction of M. D. Leighton. [Washington, 1911.]

—LAMBE, L. M. Bibliography of Canadian Zoölogy for 1910 (Exclusive of Entomology). [From the Transactions of the Royal Society of Canada, Third Series, 1911, Vol. V, Sec. IV. Ottawa, 1912.]

———. Presidential Address—The Past Vertebrate Life of Canada. [From the Transactions of the Royal Society of Canada, Third Series, 1911, Vol. V, Sec. IV. Ottawa, 1912.]

—LANE, ALFRED C. The Grain of the Igneous Rocks. Reprint of Chapter IV of the Keweenaw Series of Michigan, Publication 6, Geographical Series 4, Vol. I. [Published as a part of the Annual Report of the Board of Geological and Biological Survey for 1909. Lansing, 1911.]

———. Mine Waters. Reprint of pp. 774–79 of the Keweenaw Series of Michigan. Publication 6, Geological Series 4, Vol. I. [Published as a part of the Annual Report of the Board of Geological and Biological Survey for 1909. Lansing, 1911.]

———. Temperature of the Copper Mines. Reprint of Chapter VI of the Keweenaw Series of Michigan, Publication 6, Geological Series 4, Vol. I. [Published as a part of the Annual Report of the Board of Geological and Biological Survey for 1909. Lansing, 1911.]

—LAWSON, ANDREW C. The Recent Fault Scraps at Genoa, Nevada. [Reprinted from the Bulletin of the Seismological Society of America, Vol. II, No. 3. September, 1912.]

—LEE, G. W. The British Carboniferous Trepostomata. [Memoirs of the Geological Survey of Great Britain. Palaeontology, Vol. I, Part 3. London: T. Fisher Unwin, 1 Adelphi Terrace, May 12, 1912.]

—LEITH, C. K., AND HARDER, E. C. Hematite Ores of Brazil and a Comparison with Hematite Ores of Lake Superior. [Economic Geology Publishing Co. Reprinted from Economic Geology, Vol. VI, No. 7, October–November, 1911.]

—LEUCHS, K. Aus den wissenschaftlichen Ergebnissen der Merzbacherschen Tian-Schan Expedition. Geologische Untersuchungen im Chalyktau, Temurlyktau, Dsungarischen Alatau (Tian-Schan). [Abhandlungen der Königlich Dayerischen Akademie der Wissenschaften Mathematisch-physikalische Klasse, XXV. Band, 8. Abhandlung. München, 1912.]

—LOGAN, W. N. The Structural Materials of Mississippi. [Mississippi Geological Survey Bulletin 9. Jackson, 1911.]

—LOUGHLIN, G. F. Contribution to the Geology of the Boston and Norfolk Basins, Massachusetts. I. The Structural Relations between the Quincy Granite and the Adjacent Sedimentary Formations. [American Journal of Science, Vol. XXXII, July, 1911.]

—LOWE, E. N. Our Waste Lands. A Preliminary Study of Erosion in Mississippi. With an Appended Address on Mississippi's Agricultural

Potentialities by DR. W. J. MCGEE. [Mississippi Geological Survey. Jackson, 1910.]

———. A Preliminary Study of Soils of Mississippi. [Mississippi Geological Survey Bulletin 8. Jackson, 1911.]

—LUPTON, C. T. Coal Fields in Uinta and Wasatch Counties, Utah. [U.S. Geological Survey Bulletin 471-I. Washington, 1912.]

—MARSHALL, R. B. Results of Spirit Leveling in Alabama, 1911. [U.S. Geological Survey Bulletin 517. Washington, 1912.]

———. Results of Spirit Leveling in Illinois, 1909 and 1910. [U.S. Geological Survey Bulletin 493. Washington, 1911.]

———. Results of Spirit Leveling in Ohio, 1909 and 1910. [U.S. Geological Survey Bulletin 476. Washington, 1911.]

———. Results of Spirit Leveling in Tennessee, 1910 and 1911. [U.S. Geological Survey Bulletin 519. Washington, 1912.]

———. Results of Triangulation and Primary Traverse. For the Years 1909 and 1910. [U.S. Geological Survey Bulletin 496. Washington, 1912.]

—Maryland Geological Survey. Lower Cretaceous. [Baltimore, 1911.]

———. Prince George's County. (With Geological and Topographic Maps.) [Baltimore, 1911.]

—Maryland Geological Survey, Vol IX. [Baltimore, 1911.]

—MATTHES, F. E. Sketch of Yosemite National Park and an Account of the Origin of the Yosemite and Hetch Hetchy Valleys. [Department of the Interior. Washington, 1912.]

—MCLEISH, J. Preliminary Report on the Mineral Production of Canada, during the Calendar Year 1911. [Canada Department of Mines, No. 150. Ottawa, 1912.]

—MERWIN, H. E., AND LARSEN, E. S. Mixtures of Amorphous Sulphur and Selenium as Immersion Media for the Determination of High Refractive Indices with the Microscope. [American Journal of Science, Vol. XXXIV, July, 1912.]

—Michigan Geological and Biological Survey, 1838–1912, Catalog and Table of Contents of the Publications of the. [Ann Arbor, 1912.]

—MILLER, W. G. Reports on the District of Patricia, Recently Added to the Province of Ontario. [Report of the Bureau of Mines, 1912, Vol. XXI, Part II. Toronto, 1912.]

—MILLER, WILLIAM J. Contact Action of Gabbro on Granite in Warren County, New York. [Reprinted from Science, N.S., Vol. XXXVI, No. 928, pp. 490–92, October 11, 1912.]

———. The Garnet Deposits of Warren County, New York. [Reprinted from Economic Geology, Vol. VII, No. 5. August, 1912.]

—Mineral Resources of the United States. Calendar Year 1909. Part II. Nonmetals. [U.S. Geological Survey. Washington, 1911.]

—MOFFIT, F. H., AND CAPPS, S. R. Geology and Mineral Resources of the Nizina District, Alaska. [U.S. Geological Survey Bulletin 448. Washington, 1911.]

—MORGAN, P. G. The Geology of the Greymouth Subdivision, North Westland. [New Zealand Department of Mines, Geological Survey Branch Bulletin 13 (New Series). Wellington, 1911.]

—MORSE, EDWARD S. Biographical Memoir of Charles Otis Whitman. [Published by the National Academy of Sciences, August, 1912.]

—Museum of Comparative Zoölogy at Harvard College, Annual Report of the Curator of the, to the President and Fellows of Harvard College, for 1910–1911. [Cambridge, 1911.]

—Museums of the Brooklyn Institute of Arts and Sciences. Report for the Year 1911. [Brooklyn, 1912.]

—NEWLAND, D. H. The Mining and Quarry Industry of New York State. Report of Operations and Production during 1911. [New York State Museum Bulletin 161. Education Department Bulletin 522. Albany, July 1, 1912.]

—New York State Museum. Eighth Report of the Director of the Science Division, Including the 65th Report of the State Museum, the 31st Report of the State Geologist, and the Report of the State Paleontologist for 1911. [Education Department Bulletin 516. Albany, April 1, 1912.]

—Ontario Bureau of Mines, Twenty-first Annual Report of the. Vol. XXI, Part I. [Toronto, 1912.]

—Ouro Preto, Annaes da Escola de Minas de N. 10, 1908. [Ouro Preto: Typ. A. Castro and Comp., 8, Rua Tiradentes.]

—PARKER, E. W. A Table of Mineral Products of the United States, Calendar Years 1900 to 1909. [U.S. Geological Survey. Washington, 1911.]

—PARSONS, CHARLES L. Notes on Mineral Wastes. [Bureau of Mines Bulletin 47. Washington, 1912.]

—PEACH, B. N., WILSON, J. S. G., HILL, J. B., BAILEY, E. B., AND GRABHAM, G. W. The Geology of Knapdale, Jura and North Kintyre (Explanation of Sheet 28, with Parts of 27 and 29). [No. 28, Memoirs of the Geological Survey, Scotland. Edinburgh, 1911.]

—PHILLIPS, WILLIAM B. Iron Making in Alabama. (Third Edition.) [Geological Survey of Alabama. University, 1912.]

—PORTER, H. C., AND OVITZ, F. K. The Deterioration and Spontaneous Combustion of Coal in Storage. [U.S. Geological Survey Bureau of Mines Technical Paper 16. Washington, 1912.]

—PORTER, J. B., AND DURLEY, R. J. An Investigation of the Coals of Canada with Reference to Their Economic Qualities: as Conducted at McGill University, Montreal; under the Authority of the Dominion Government. Vol. II. [Canada Department of Mines. Ottawa, 1912.]

—PROUTY, WILLIAM. Map of the Coosa Coal Field with Vertical and Horizontal Sections. [Geological Survey of Alabama. University, 1912.]

—PURDUE, A. H. The Zinc Deposits of Northeastern Tennessee. [State Geological Survey Bulletin 14. Nashville, 1912.]

—RABOT, C., ET MURET, E. Les variations périodiques des glaciers. XVII^me^ Rapport, 1911. [Extrait des Annales de glaciologie, t. VII, septembre 1912, pp. 37–47. Berlin: Borntraeger Frères, 1912.]

—REEDS, C. A. The Hunton Formation of Oklahoma. [From the American Journal of Science, Vol. XXXII, October, 1911.]

—Resources of Tennessee, The. Vol. I, No. 1, July, 1911. No. 4, October, 1911. [Tennessee Geological Survey. Nashville.]

—Resources of Tennessee, The. Vol. I, No. 5, November, 1911. Vol. I, No. 6, December, 1911. [Tennessee Geological Survey. Nashville.]

—RICE, GEORGE S. Coal-Dust Explosions. [Bureau of Mines Miners' Circular 3. Washington, 1911.]

———. Mine Fires; A Preliminary. [Bureau of Mines Technical Paper 24. Washington, 1912.]

—RIES, H. The Clay and Shale Deposits of the Western Provinces of Canada. [Journal of the Canadian Mining Institute, part of Vol. XIV, 1912.]

———. A Review of the Theories of the Origin of White Residual Kaolins. [Transactions of the American Ceramic Society, Vol. XIII, 1911.]

—RIGGS, E. S. New or Little Known Titanotheres from the Lower Uintah Formations. [Field Museum of Natural History Publication 159. Geological Series, Vol. IV, No. 2. Chicago, June, 1912.]

—ROGERS, A. W. Geological Map of the Province of the Cape of Good Hop Sheet XIX. [Geological Commission. Cape Town, 1912.]

—ROMER, E. Bericht über geographische Arbeiten im Gebiete des Sichoto-Alin-Gebirges. [Extrait der Bulletin de l'Academie des sciences de Cracovie. Classe des Sciences mathématiques et naturelles. Série 4: Sciences mathématiques. Février 1912. Cracovie: Imprimerie de l'Université, 1912.]

—SCHALLER, W. T. Crystallized Variscite from Utah. [No. 1867. Proceedings of the U.S. National Museum, Vol. XLI, pp. 413–30, with Plate 33. Washington, January 31, 1912.]

———. Meteorological Notes, Series 2. [U.S. Geological Survey Bulletin 509. Washington, 1912.]

—Schimmel and Company, Semi-Annual Report of. [Miltitz (near Leipzig), London, New York. April, 1912.]

—SCHUCHERT, C. Paleogeographic and Geologic Significance of Recent Brachiopoda. Proceedings of the Paleontological Society. [Reprinted from the Bulletin of the Geological Society of America, Vol. XXII, pp. 258–75. Published June 23, 1911.]

—SCHWARZ, E. H. L. Selective Absorption of Substances in the Earth's Crust. [South African Journal of Science. Cape Town, January, 1912.]

—SEARLE, A. B. The Natural History of Clay. [Cambridge: The University Press; New York: Putnam, 1912.]

The Mechanistic Conception of Life

Biological Essays by

Jacques Loeb

Head of the Department of Experimental Biology Rockefeller Institute for Medical Research

THE achievements of Professor Jacques Loeb in the field of experimental biology have made him so widely known as to insure any book of his a large and interested circle of readers.

In his latest work, *The Mechanistic Conception of Life*, Professor Loeb presents many of the current problems in biology on which he has been engaged in recent years. These may be characterized in a general way as an attempt to analyze life from a purely physicochemical standpoint.

238 pages, 12mo, cloth *Postpaid, $1.65*

The University of Chicago Press
Chicago - - - - Illinois

A Manual for Writers

By JOHN M. MANLY and JOHN A. POWELL

A book designed to aid authors and all others who are concerned with the writing of English. It aims to answer the practical questions that constantly arise in the preparation of manuscripts for the printer, business letters, and any sort of composition where correctness of form is an important element.

It treats in a clear and convenient way the matters of grammar, spelling, and general form which writers need most to be informed about, and gives full directions on the preparation of "copy" for the printer and the correcting of proof. The chapter on letter-writing is unique and gives just the help that is constantly wanted and that other manuals deny.

224 pages. 12 mo, cloth. :: Postpaid, $1.10

The University of Chicago Press
Chicago, Illinois

ORDERS and inquiries from individual buyers of books in quantities, schools, and libraries solicited. The most prompt and complete shipment of orders, at lowest prices for all parts of the country—the best service in the United States.

Ask us to send you our

STANDARD LIBRARY CATALOGUE

and

The Monthly Bulletin *of the* Latest and Best Selling Books

We are the Trade Agents in the East for
THE UNIVERSITY OF CHICAGO PRESS PUBLICATIONS

THE BAKER & TAYLOR COMPANY

Publishers and dealers in the books of all publishers

33-37 East 17th Street **NEW YORK CITY** **Union Square North**

READY IN OCTOBER

ANIMAL COMMUNITIES IN TEMPERATE AMERICA

A STUDY IN ANIMAL ECOLOGY

Designed to serve as a reference work and textbook in the New Science of Animal Ecology

By **VICTOR ERNEST SHELFORD**

of the Department of Zoölogy of the University of Chicago

Illustrated with 300 figures, maps, and diagrams

This volume by Dr. Shelford presents the principles of field ecology, illustrated by the more widely distributed animal habitats of the eastern half of temperate North America, and the aquatic habitats of a much larger territory. The material has been accumulated during ten years of field study, from the point of view of modern ecology, in various parts of the United States, though most of the material is drawn from the Chicago Region. The book is designed to serve as a reference work and a textbook in the new science of field ecology.

380 pp., 8vo, cloth; postpaid $3.22

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO *ILLINOIS*

PUBLICATIONS IN THE
PHYSICAL SCIENCES

OUTLINES OF GEOLOGIC HISTORY, WITH ESPECIAL REFERENCE TO NORTH AMERICA **Edited By Rollin D. Salisbury**
A series of Essays Involving a Discussion of Geologic Correlation, Presented before Section E of the American Association for the Advancement of Science in Baltimore, December, 1908. 314 pp., 8vo, cloth; net $1.50, postpaid $1.66.

THE STUDY OF STELLAR EVOLUTION **By George Ellery Hale**
An account of some modern methods of Astrophysical Research. 250 pp., 104 plates, 8vo, cloth; net $4.00, postpaid $4.27.

QUANTITATIVE CLASSIFICATION OF IGNEOUS ROCKS **By Whitman Cross, Joseph Iddings, Louis V. Pirsson, and Henry S. Washington**
286 pp., 8vo, cloth; net $1.75, postpaid $1.91.

LIGHT WAVES AND THEIR USES **By Albert A. Michelson**
With 108 drawings and three colored plates. 174 pp., 8vo, cloth; net $1.50, postpaid $1.63.

PHYSICAL CHEMISTRY IN THE SERVICE OF THE SCIENCES
With illustrations. By **Jacobus H. van't Hoff**, Professor Ordinarius of the University of Berlin. Translated by **Alexander Smith.** xviii+126 pp., 8vo, cloth; net $1.50, postpaid $1.62.

THE RÔLE OF DIFFUSION AND OSMOTIC PRESSURE IN PLANTS. **By Burton E. Livingston**
xiv+150 pp., 8vo, cloth; net $1.50, postpaid $1.62.

ADDRESS DEPARTMENT P

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

Light Waves and Their Uses

By Albert A. Michelson

1. Wave Motion and Interference.
2. Comparison of the Efficiency of the Microscope, Telescope, and Interferometer.
3. Application of Interference Methods to Measurements of Distances and Angles.
4. Application of Interference Methods to Spectroscopy.
5. Light Waves as Standards of Length.
6. Analysis of the Action of Magnetism on Light Waves by the Interferometer and the Echelon.
7. Application of Interference Methods to Astronomy.
8. The Ether.

With 108 text figures and three full-page lithographs.

Numerous practical applications of recent theories in optics together with accurate illustrations and descriptions of apparatus add materially to the value of this book. Students of physics and astronomy will find here an admirable condensation of the somewhat scattered literature of the subject, presented in an original and entertaining manner.

Price $1.50 net; $1.63 postpaid.

The University of Chicago Press
Chicago, Illinois

Outlines of Geologic History with Especial Reference to North America

Symposium Organized by
BAILEY WILLIS
Compilation Edited by
ROLLIN D. SALISBURY

GEOLOGISTS and all readers of geologic literature will welcome the publication, in book form, of an important series of essays and discussions on the subject of geologic correlation under the title, *Outlines of Geologic History with Especial Reference to North America*.

They embody the present state of knowledge and opinion concerning many of the fundamental problems of North American geology and form an admirable supplement to earlier treatises and manuals.

The value of the book is greatly enhanced by the fifteen paleogeographic maps by Bailey Willis which accompany the papers.

316 pages 8vo cloth $1.66 postpaid

The University of Chicago Press
Chicago - - - Illinois

THE STUDY OF STELLAR EVOLUTION

An Account of Some Modern Methods of Astrophysical Research

By GEORGE ELLERY HALE, Director of the Solar Observatory of the Carnegie Institution, Mount Wilson, California.

"The Study of Stellar Evolution" explains, in a popular way, how the life-histories of the sun and stars are investigated. A brief historical sketch, in which the general purposes and methods of astrophysical research are outlined, is followed by several chapters on the sun, the only star that is near enough the earth to be studied in detail. An account of the spectroheliograph, which gives pictures of the sun, showing the *flocculi*—invisible clouds of calcium or iron vapor, or of hydrogen gas—introduces a series of chapters describing recent methods of solar and stellar research developed at the Yerkes and Mount Wilson observatories.

250 pages 104 plates 8vo, cloth Postpaid, $4.27

The University of Chicago Press
Chicago - - - Illinois

Heredity and Eugenics

By **John M. Coulter, William E. Castle, Edward M. East, William L. Tower, and Charles B. Davenport**

THIS book consists of a series of public lectures delivered at the University of Chicago. The lectures were given partly by members of the University Faculty, and partly by investigators from other institutions. As all these men are distinguished for work in these fields, the subject is summarized in an unusually authoritative way. The purpose of the volume is to present to the intelligent public an account of the more important and interesting movements in biology. It is profusely illustrated.

312 pages, 8vo, cloth ***Postpaid $2.70***

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO, ILLINOIS

American Permian Vertebrates

By SAMUEL W. WILLISTON

THIS work comprises a series of monographic studies, with briefer notes and descriptions of new or little-known amphibians and reptiles from the Permian deposits of Texas and New Mexico. The material upon which these studies are based was for the most part collected during recent years by field parties from the University of Chicago. The book is offered as a contribution to knowledge on the subject of ancient reptiles and amphibians, with such summaries and definitions based chiefly on American forms as our present knowledge permits. The work is illustrated by the author.

228 pages *8vo, cloth* *Net $2.50* *Postpaid $2.68*

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO - - - - - ILLINOIS

CS

,

rsity of
versity
l these
in an
to the
ents in

$2.70

ESS

tes

riefer
s and
exico.
r the
ersity
n the
s and
e per-

$2.68

S
NOIS